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AN INVESTIGATION OF BOTTOM CHANGES  
IN MONTEREY HARBOR (1932-1969)

by

Richard John Lennox



# United States Naval Postgraduate School



## THESIS

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June 1969

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IN MONTEREY HARBOR (1932-1969)

by

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ABSTRACT

Bottom changes occurring in Monterey Harbor from 1932-1969 were analyzed by numerical computer methods using 15 selected hydrographic surveys. Results of the study indicate that the major portion of the harbor has been shoaling in the mean since 1932. The long-term shoaling rate has been 0.4 to 4.0 feet per decade in the beach and nearshore zones and along the breakwater; and less than 0.25 feet per decade in the stable outer harbor. The accretion rate averaged 17,500 cubic yards per year from 1932-1969 but only 7,100 cubic yards per year from 1947 to 1969. The shoaling is believed due to the construction of the Coast Guard Breakwater in 1931-1934. It is deduced that prior to 1960 the excess sand was carried into the harbor by littoral transport from Del Monte Beach and by wave currents around the breakwater. Construction of the solid wall on Wharf 2 in 1960 cut off the former sand supply. Local redistribution of sand in the beach and nearshore zones of the harbor is large and results in areas of significant accretion and erosion between surveys. Dredging operations have had only short-term effectiveness because the spoil has been retained within the harbor.

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## I. INTRODUCTION

### A. PURPOSE AND SCOPE

The objective of the research described in this thesis was to study bottom changes in Monterey Harbor (Figures 1 and 2) from 1932 to 1969 by comparison of successive hydrographic surveys. Specific questions of interest were: Is the harbor shoaling or eroding with time? If there has been long-term accretion or erosion, what are the sediment sources and losses? Are there seasonal changes or other patterned bottom changes that may be noted? What influence has local construction and dredging had on sedimentation in the harbor? Have dredging operations been effective?

The hydrographic surveys used in this study were all made by the Corps of Engineers except for the most recent one which was made by this investigator in January 1969. The latter survey was made in order to provide bottom-change information covering the period from the last Corps of Engineers survey in 1963 to the present.

In the course of this study a series of computer programs were developed which were used to contour surveys, to compute the changes in bottom topography and sediment volumes occurring between two surveys, and, using a series of surveys, to determine any long-term trends of erosion or deposition in any part of the harbor. These computer programs are readily applicable to other areas.

Limitations encountered in the study were the absence of sufficiently detailed hydrographic surveys of Monterey Harbor prior to 1932, the uneven distribution in time of the hydrographic surveys conducted from 1932 to 1969, and the poorly recorded data concerning dredging operations in Monterey Harbor carried out by the City of Monterey and the Corps of Engineers.



U.S. NAVY PHOTOGRAPH

Figure I. Aerial Photograph of Monterey Harbor

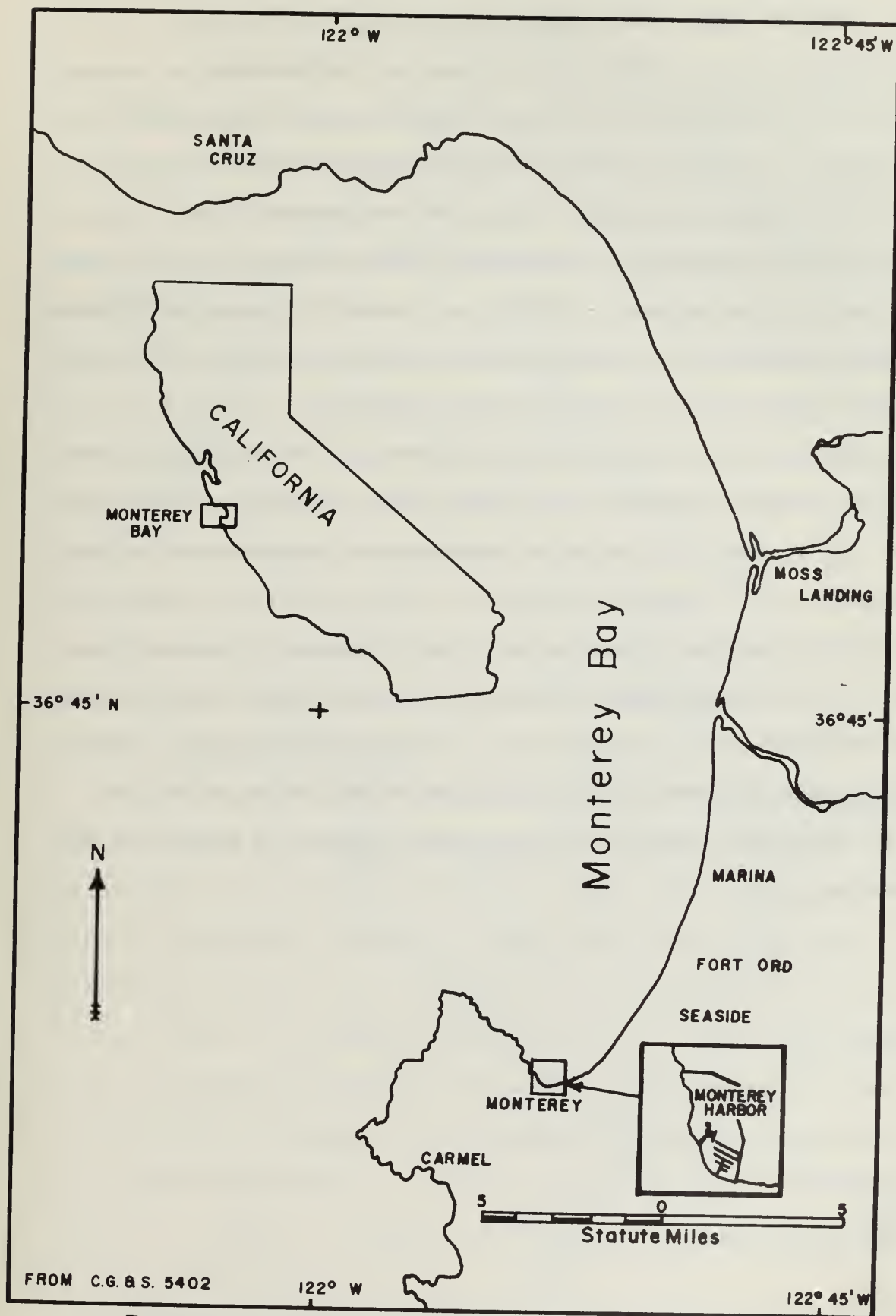


Figure 2. Monterey Harbor Location Map



## B. PREVIOUS BOTTOM-CHANGE STUDIES

Two previous studies of bottom change and sedimentation in Monterey Harbor have been made by the Corps of Engineers. The first study is contained in a report on Monterey Harbor printed in House Document No. 266, 76th Congress, 1st Session, 1939, and was concerned with shoaling between Wharf 1 and Wharf 2 from 1932 to 1938 (see Figure 3). The report indicated that approximately 100,000 cubic yards of sediment was deposited between the wharves and attributed this accretion to littoral drift entering the area from the beach to the east of Wharf 2.

The second study by the Corps of Engineers is printed in House Document No. 219, 86th Congress, 1st Session, 1959, and deals with the period from 1851 to 1949. This study was prompted by a recommendation for the construction of a companion breakwater to extend out from Del Monte Beach to provide for a larger harbor. The findings of this report showed that the area between Wharf 1 and Wharf 2 was shoaling at the approximate rate of 14,000 cubic yards per year. It was believed that the proposed breakwater would serve to act as a barrier to this influx of sediment while not making significant changes to the coastline on either side of the harbor.

## C. DESCRIPTION OF THE HARBOR

### 1. Geography and Key Harbor Structures

Monterey Harbor lies at the extreme southern end of Monterey Bay approximately sixty nautical miles south of San Francisco (Figure 2). The general shape of the harbor and location of key structures within the harbor are shown in Figure 3. The harbor is contained on the north by the Coast Guard Breakwater and on the west by a rocky shoreline extending from the breakwater to Wharf 1. The southern boundary between Wharf 1 and Wharf 2 is a sand beach which continues upcoast as the coastline of Monterey Bay. The eastern limit of the harbor is Wharf 2. There is a marina in the southern corner of the harbor enclosed by the frontal and east walls. The northern half of the harbor is used as a boat anchorage. Details of the harbor plan may be seen in the aerial photograph in Figure 1.

The general topography of the harbor bottom is shown in Figure 4; the hydrography shown is that of the January 1969 survey.

### 2. Geology and Sediments

The rocky shoreline between Wharf 1 and the Coast Guard Breakwater, and the rock outcrops in the shallow water in this area, are granodiorite of the Santa Lucia Formation (Cretaceous). The bottom in this area is sometimes covered with several feet of sand. The rock underlying the eastern side of the harbor in the vicinity of Wharf 2 is siliceous shale of the Monterey Formation (Miocene). The contact between these two lithologic structures is not exposed and its location is not accurately known. Elsewhere on the Monterey Peninsula the contact between these formations may be seen to be depositional (personal communication with Dr. Warren C. Thompson), but the proximity of the Tularicitos

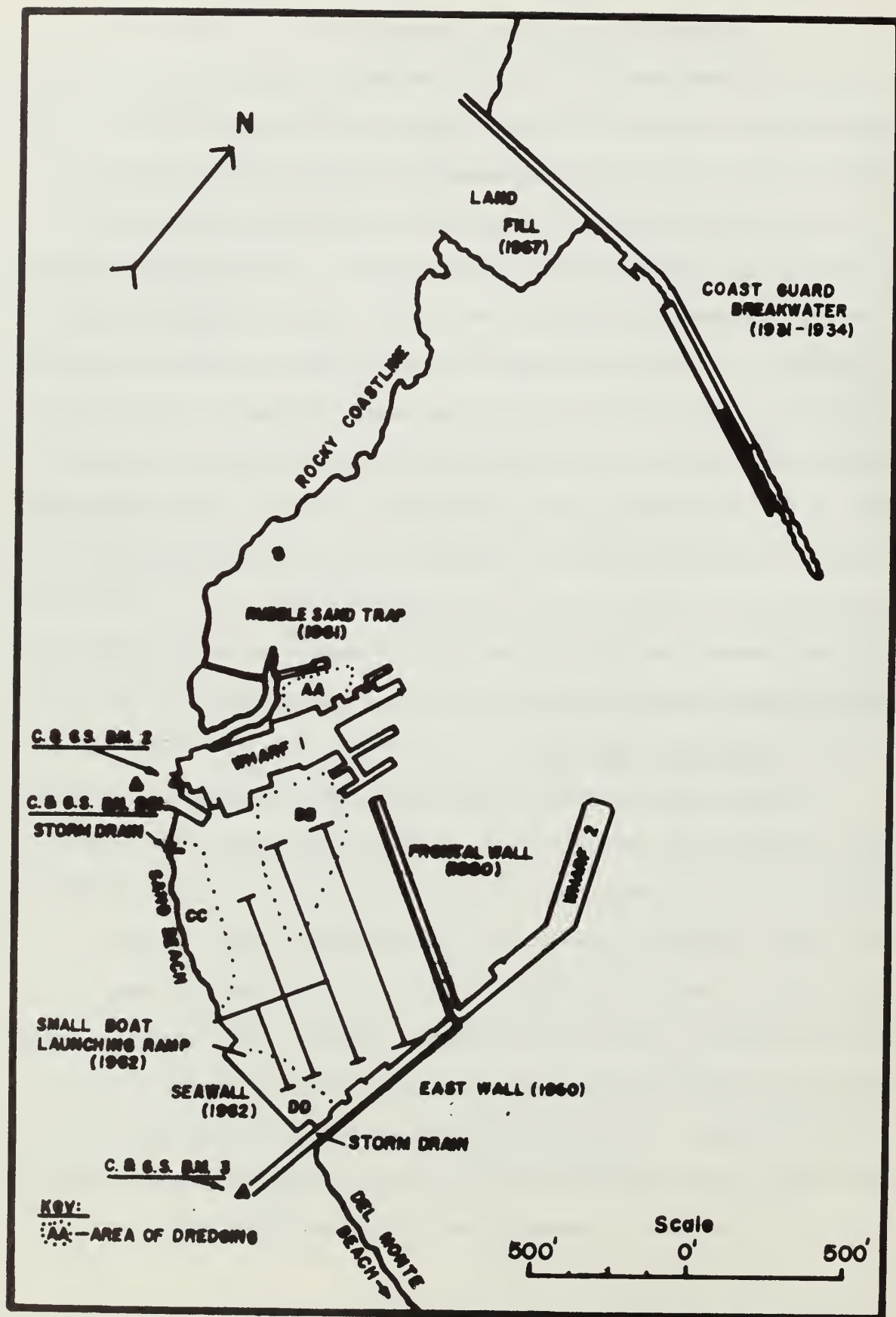


Figure 3. Location of Key Structures in Monterey Harbor

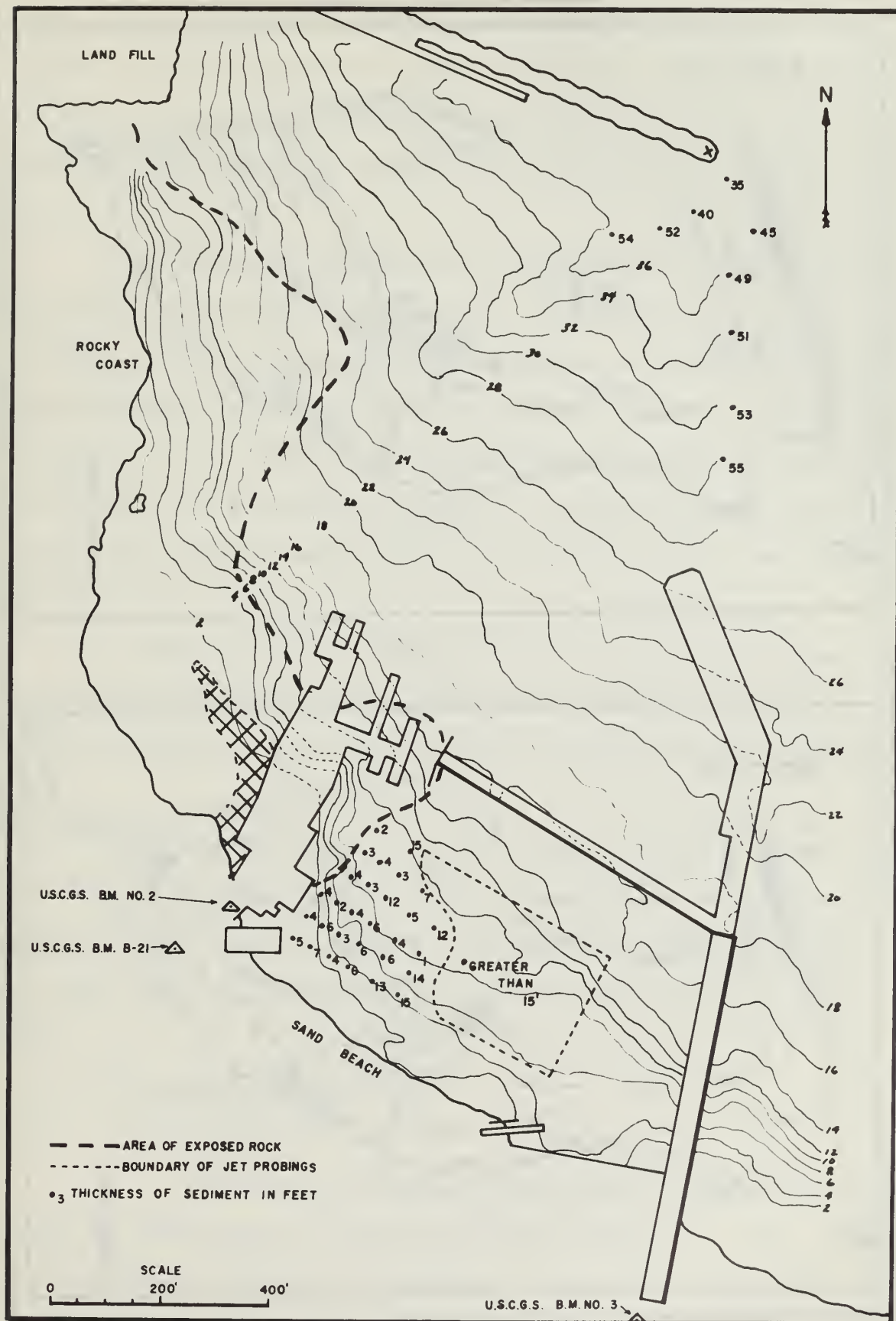


Figure 4. Monterey Harbor Hydrographical Features



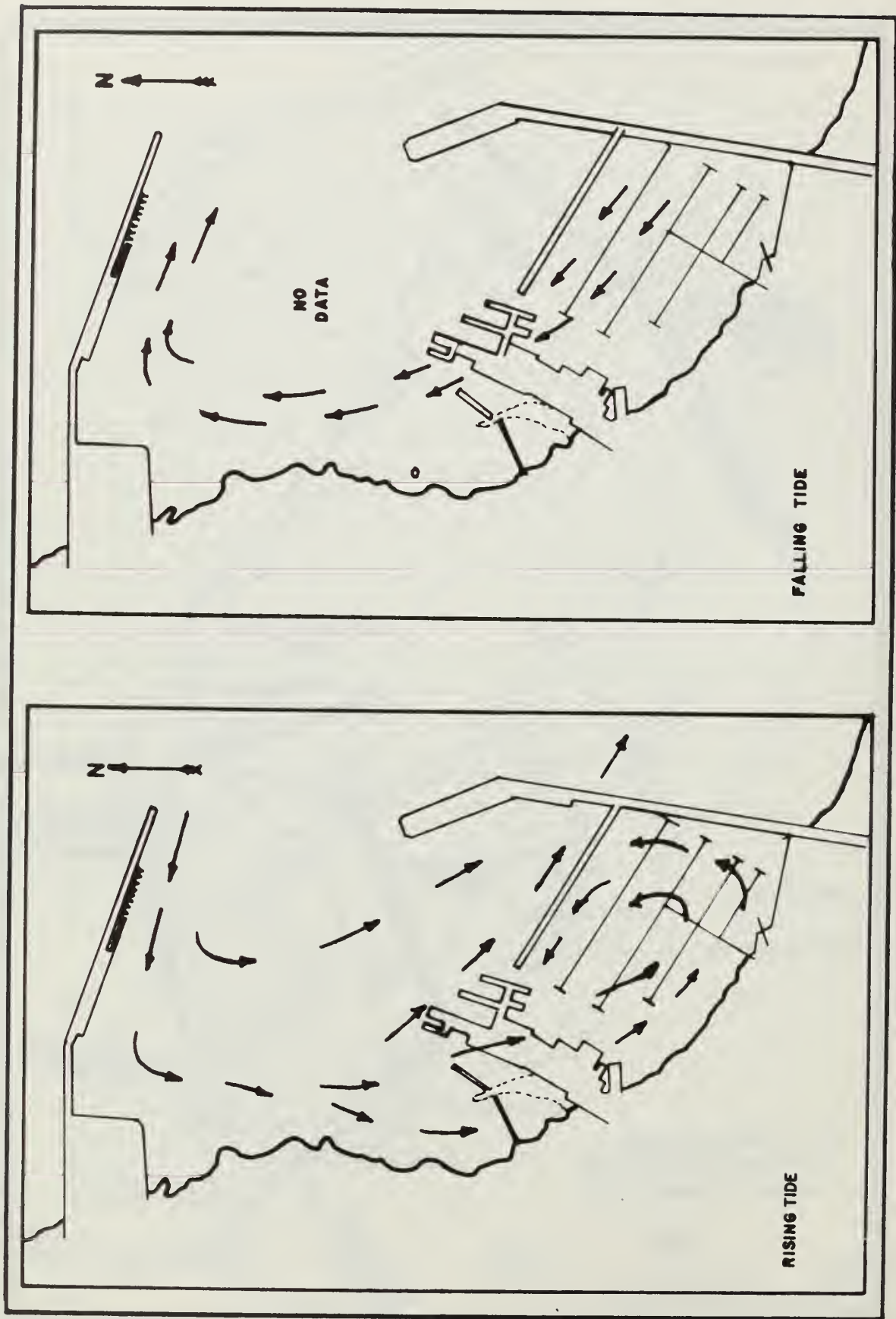


Figure 5. Tidal Currents in Monterey Harbor  
(FROM BREIDENSTEIN & THOMAS, 1965)



Fault to Monterey Harbor (preliminary geological map provided by Robert S. Ford, California Department of Water Resources), could indicate that the contact in the harbor is an extension of this fault system. Thus, it is not clear whether the contact is of a depositional or faulted nature.

The thickness of sediments on the harbor floor is known over part of the harbor from observed outcrops, from borings made by the Corps of Engineers in 1947 (Corps of Engineers Drawing No. 6-13), and from sub-bottom profiles run by the Corps of Engineers in 1966 (Corps of Engineers Drawing No. 6-5-3). The area of exposed rock and the sediment thickness at the boring sites are shown in Figure 4. Immediately to the east of Wharf 2 the bottom is exposed shale in water depths greater than 15 to 20 feet.

Figure 4 shows that thick fill occurs on the bottom through the marina and the seaward end of the Coast Guard Breakwater. This is believed to indicate an old drainage channel extending out from El Estero Lake.

The sediment composition in the harbor was shown by Dorman (1968) to be fine sand on the beach and nearshore area between Wharves 1 and 2, medium to coarse sand from Wharf 1 to the Coast Guard Breakwater along the rocky coast, and a mixture of very fine sand and silt in the outer harbor.

### 3. Currents and Waves

#### a. Currents

Breidenstein and Thomas (1965) measured currents inside the harbor and found them to be tidally controlled (Figure 5). These currents are predominantly weak and it is therefore questionable as to whether they

are a significant agent for the transport of sand within the harbor. Currents off the harbor and off Del Monte Beach immediately upcoast from the harbor are also reported to be weak. While these weak currents are unlikely agents for the transport of sand, they are of sufficient strength to carry silt-sized sediment into the harbor area.

Littoral currents on the beach just east of Wharf 2 are predominantly weak or non-existent as indicated by the Corps of Engineers (1959), Koehr, Rohrbough, and Thompson (1964), Hohenstein, Jaeger, and Jones (1965), and Dorman (1968). The lack of an appreciable accumulation of sediments against the upcoast side of the solid bulkhead portion of Wharf 2 (built in 1959-1960) confirms this conclusion. Through the use of hindcast wave and swell data prepared by National Marine Consultants (1960) and wave-refraction information provided by Dr. Warren C. Thompson, this investigator, in conjunction with LT Craig E. Dorman, determined that a weak net current in the upcoast direction exists at a point approximately 2 miles east of Wharf 2.

#### b. Waves

Monterey Harbor is so protected in the southern end of the bay that waves cannot reach it from the open ocean without undergoing extensive refraction. Wilson, Hendrickson, and Kilmer (1965) show through the use of refraction diagrams that swell arrival at the harbor is almost unidirectional from the north-northeast. Wind waves generated in the harbor area are uncommon but are occasionally produced by north winds blowing the length of the bay.

Storm waves resulting in damage to boats, structures, and the shoreline in and near the harbor were investigated by Bixby (1962), who described the synoptic characteristics of storms and their frequency

of occurrence over the fifty-year period from 1910 to 1960. Bixby's investigation revealed that storm waves at Monterey Harbor are generated by two synoptic weather situations which he called Open Ocean Storms and Bay Wind Storms. Open Ocean Storms are generated by west to southwest winds blowing over long ocean fetches; the waves resulting are diminished considerably by refraction before they reach the harbor. Bay Wind Storms generate rough seas within the bay from the north. The configuration of the southern end of the bay is such that Bay Wind Storms may create significant littoral drift southward along Del Monte Beach toward the harbor. Bixby calculated the frequency of important Bay Wind Storms to be once every seven years.

#### D. HARBOR CONSTRUCTION AND DREDGING

Familiarity with the chronological sequence of harbor structures and dredging operations is essential for inquiring into their effects on bottom changes observed through the years. A listing of both harbor construction and dredging operations that are considered significant is presented in Table I. Figure 3 shows the location of the various structures and dredging areas.

It can be seen from Figures 2 and 3 that prior to the construction of the Coast Guard Breakwater (1931-1934) the only protection afforded the harbor from storm waves from the open ocean was its natural location in the lee of the Monterey Peninsula. After completion of the 1750-foot impermeable rubble breakwater by the Corps of Engineers, the harbor received added protection from the north. Additional protection of the inner harbor was gained upon completion of the east wall and frontal wall of the marina. This solid wooden bulkhead was built in 1959-1960.

TABLE I

## SIGNIFICANT HARBOR CONSTRUCTION AND DREDGING

Refer to Figure 3 for the location of the below-mentioned harbor works.

<u>Dates</u>	<u>Description</u>
Dec 1931 - Mar 1934	Construction of the Coast Guard Breakwater.
Feb 1947	First major dredging in Monterey Harbor. Corps of Engineers dredged 58,520 cu yds of sand in areas AA and BB; spoil placed on beach between Wharves 1 and 2.
May 1950	Dredging by Corps of Engineers removed an unrecorded amount of sand from area BB and placed spoil on beach between Wharves 1 and 2.
Dec 1952 - Jan 1953	Healy Tibbits Construction Company dredged approximately 20,000 cu yds of sand from west side of Wharf 1 in area AA and placed spoil in beach area as fill.
Aug 1953 - Aug 1954	Dredging by Corps of Engineers removed 12,049 cu yds of sand from area BB placing spoil on beach area as fill.
May - Jun 1957	Dredging by Corps of Engineers removed 8,223 cu yds of sand from area BB and placed spoil in beach area.
Oct 1959 - Aug 1960	Construction of perimeter wall: East wall completed June 1960 and frontal wall completed Aug 1960.

<u>Dates</u>	<u>Description</u>
Jun 1961	Dredging by City of Monterey in southeast corner of marina moved approximately 2,000 cu yds of sand to outer harbor area in depths greater than 20 ft.
Oct 1961	Construction of Rubble Groin (sand trap) to west of Wharf 1.
Mar 1962	Dredging operations conducted by City of Monterey to remove sand between Wharves 1 and 2 in area CC; spoil placed in area of sand trap.
Apr 1962	Construction of Sea Wall in southeast corner of marina by Granite Construction Co.
Jun 1962	Construction of Small Boat Launching Ramp. Dredging operations in vicinity of ramp to fill promenade area behind new sea wall.
Apr - May 1963	Dredging in southeast corner of marina by Granite Construction Co. Approximately 4,000 cu yds of spoil placed behind sea wall in present promenade area.
Jun - Nov 1963	Dredging operations in vicinity of Small Boat Launching Ramp by City of Monterey. Unrecorded amount of spoil placed on beach and behind sea wall.
Jun - Aug 1964	Dredging operations by Granite Construction Co. removed approximately 12,000 cu yds of sand from marina area DD; spoil placed in



<u>Dates</u>	<u>Description</u>
1965 - 1967	outer harbor and in area of rubble trap. Dredging operations conducted by City of Monterey Harbor crew removed approximately 6,000 cu yds of sand from boat tier area of marina; spoil used to replace depleted beach between Wharves 1 and 2.
Jan 1967	Dredging operations conducted by City of Monterey removed 23,000 cu yds of sand from area between Wharves 1 and 2; spoil was used as fill for the northwest corner of the harbor.

Note: Intermittent dredging by the Monterey Harbor Maintenance Crew has removed an unrecorded amount of sand from the beach between Wharves 1 and 2 at low tide. This spoil was redistributed on this same beach above the high water line.

## II. PROCEDURES

This section of the thesis describes the hydrographic surveys, the delineation of the boundary of the area of study around the harbor, and the procedures used for handling the data. A portion of this section is also devoted to the hydrographic survey of Monterey Harbor made by this investigator in January 1969.

### A. HYDROGRAPHIC SURVEY REDUCTION

#### 1. Selection of Surveys

Fifty-six hydrographic surveys of the harbor and the bay immediately adjacent covering the time span from 1851-1969 are known to have been made, all of them except the one made by this investigator in 1969 having been conducted by the Corps of Engineers and the Coast and Geodetic Survey. A list of these surveys is contained in Appendix D.

These charts vary greatly in scale, sounding density, accuracy of depth measurement, and areal coverage of the harbor; accordingly, selection was made of charts which provide sufficient coverage and depth information. The criteria for selection were as follows: (1) The survey had to cover essentially the entire harbor; partial surveys were not considered. (2) The scale of the survey could be no smaller than 1" = 200'. (3) There had to be a sufficient density of soundings within the harbor area so that depths could be interpolated accurately at fifty-foot grid points. When these criteria were used, the original 56 charts were reduced in number to only 14 Corps of Engineers charts covering the period 1932 through 1963 and the 1969 survey made by this investigator. The 15 surveys have been numbered chronologically from 1932 (Survey 1) to 1969 (Survey 15). The survey number, survey date, scale, and identification of the 15 surveys are listed in Table II.

TABLE II

## SURVEYS USED IN THE STUDY

<u>Survey Number</u>	<u>Survey Date</u>	<u>Scale</u>	<u>Corps of Engineers Drawing Number</u>
1	1932 AUG	1" = 50'	6-2-12
2	1934 MAR	1" = 200'	6-2-13
3	1935 JUL	1" = 200'	6-2-14
4	1935 OCT	1" = 200'	6-2-15
5	1937 SEP	1" = 200'	6-2-16
6	1938 JUL	1" = 200'	6-2-17
7	1945 NOV	1" = 200'	6-9
8	1947 JAN	1" = 200'	6-12
9	1948 FEB	1" = 200'	6-14, 6-2-21
10	1949 JUN	1" = 200'	6-18, 6-2-22
11	1951 SEP	1" = 100'	6-22, 6-2-23
12	1952 MAR	1" = 100'	6-23, 6-2-24
13	1954 AUG	1" = 100'	6-26, 6-2-26
14	1963 AUG	1" = 100'	6-2-31
15	1969 JAN	1" = 100'	None

\*Survey No. 15 was made by this investigator on 22 and 29 January 1969.



The scales of the 15 charts used included 1" = 50' (1932 survey), 1" = 100', and 1" = 200' (mainly in 1930's and 1940's). For this work, the most desirable of the three scales is 1" = 50' because it provides the greatest sounding density and accordingly allows the most accurate interpolation of water depths at selected grid points. It was felt that by careful contouring, the depths at fifty-foot grid points on the 1" = 200' scale charts could be interpolated to an accuracy of 0.1 foot.

## 2. Contouring and Area Grid

The Corps of Engineers surveys as received were contoured at six-foot intervals. All of the charts used in this study were carefully recontoured by hand by this investigator to a one-foot interval.

Upon completion of the contouring, a north-south oriented fifty-foot square grid covering the area of study was established for extracting the depth information from the surveys for use in a computerized format. Figure 6 shows how the grid system was superimposed upon the harbor, and indicates the locations of three Coast and Geodetic Survey Tidal Bench Marks used to insure the exact placement of the grid on individual charts.

The area investigated in this study is delineated by the irregular heavy line shown in Figure 6. This area varies slightly for different surveys because of the lack of sounding information in one or more sections of the harbor. The boundary of the area used for each survey comparison may be seen in Appendix B.

Following placement of the grid on a contoured chart, a depth value was read at each grid point contained within the area of study. These depth values were interpolated to 0.1 foot using linear interpolation between contours. The total number of grid-point readings varied



from 1544 to 1211 according to the area actually covered by each survey comparison as shown in Appendix B. These depth values were then placed on computer cards and were run through an initial computer program which provided a reduced number of data cards for easier handling, and a printout of the depth values. The printed output of depth values provided a means of checking to be sure that the proper depth values were associated with the proper grid points.

The computer also reproduced the 15 charts from these depth data for illustration purposes, and these are shown in Appendix A. The machine-drawn contours are plotted at a two-foot depth interval because of the chart scale.

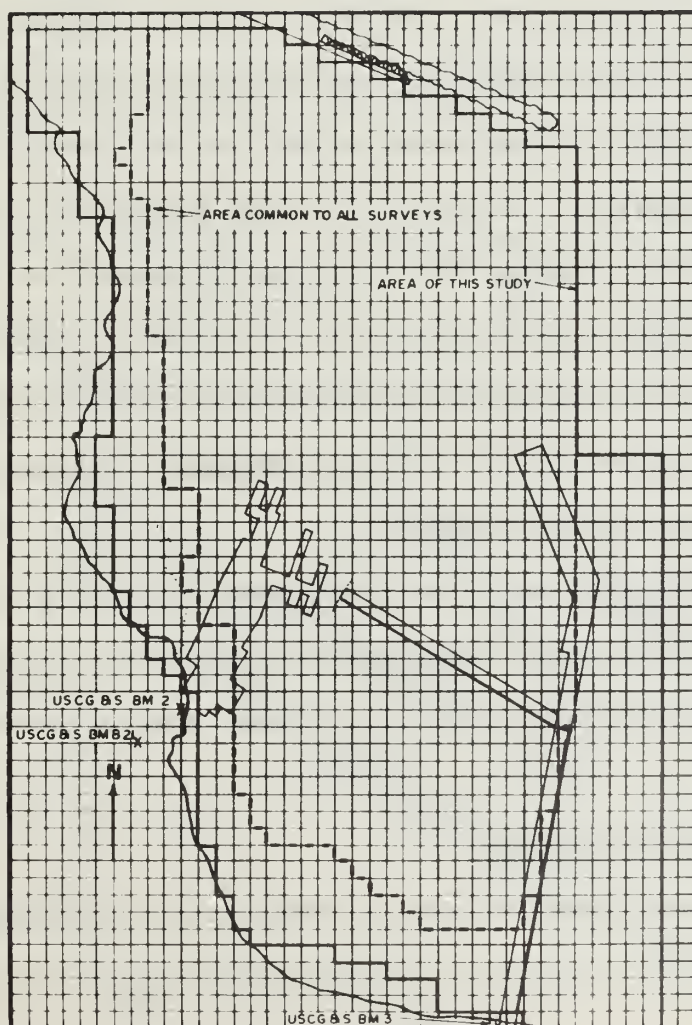


Figure 6 Area of Study and Numerical Analysis Grid

## B. COMPUTER ANALYSIS

The comparison of one hydrographic survey with another was done using numerical techniques with the aid of a computer. The steps taken in handling the hydrographic data are explained below. Copies of the programs used may be found in Appendix E along with a brief explanation of their application.

### 1. Depth Difference

In order to obtain the change in depth at each grid point the data decks for the two surveys to be compared were placed in the computer using Program DIFFERENCE. Program DIFFERENCE provides an output in two forms. The first output is in the form of data cards which contain the depth-change values. This information was used as the input for subsequent programs and subroutines. The second output, constructed by Subroutine METMAP, is a printed numerical output in the form of a contoured map of the depth changes in the harbor between the two surveys. It was used for a gross analysis of the areas of change and is not illustrated.

A second program, SCAN, was used to produce a contour map of harbor bottom changes occurring between two surveys. Figure 7 is an example of the output of the Program SCAN and shows contoured changes indicating areas of accretion and erosion. The charts contained in Appendix B were drawn using this program.

Program SCAN and Subroutine METMAP may also be used to plot contours of the bottom directly using any desired contour intervals. Appendix A is an example of contouring with Program SCAN at two-foot intervals.

### 2. Volume Computation

Program VOLUME was used to obtain the volume change between

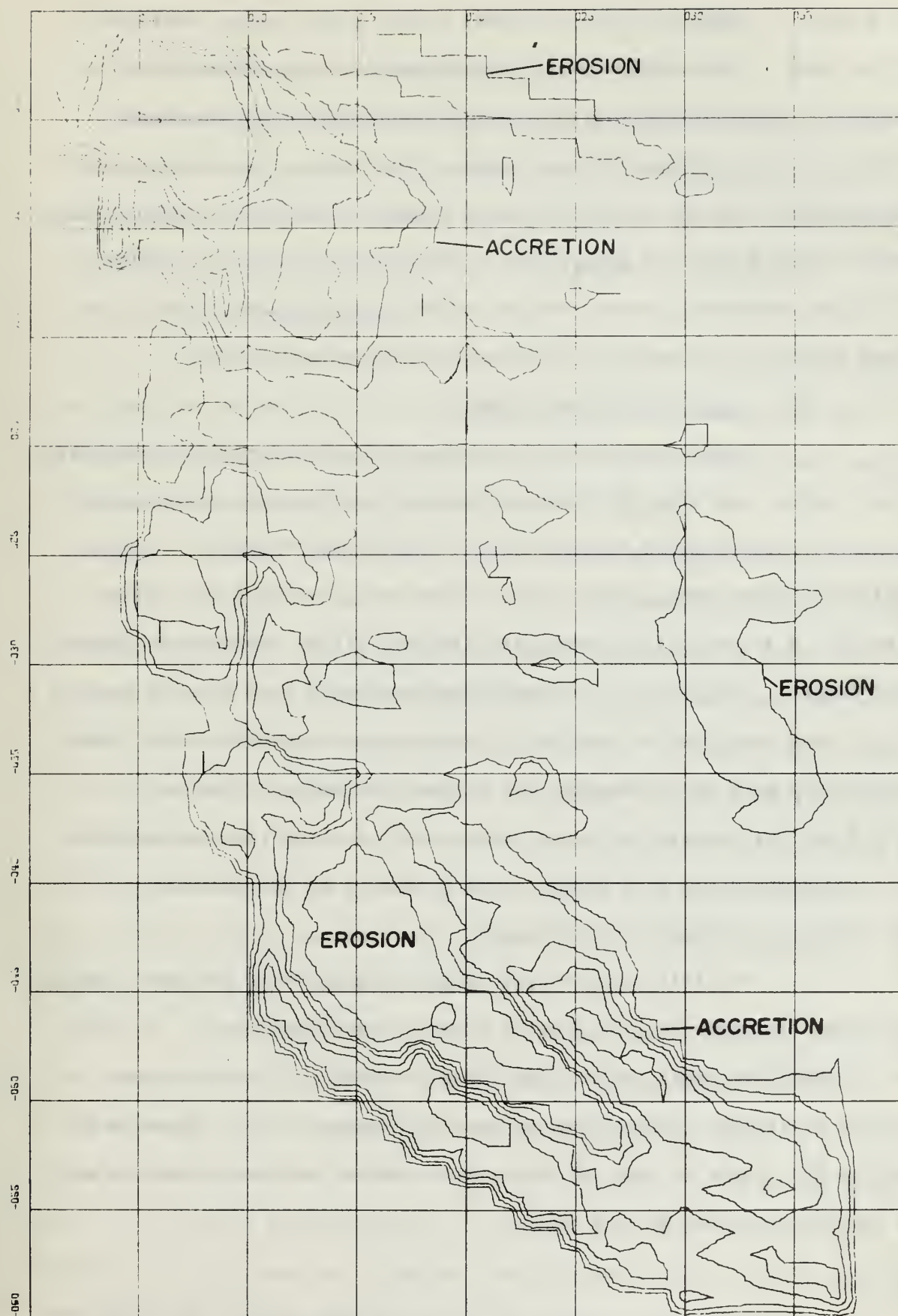


Figure 7. Scan Output: Contours of Bottom Change



two surveys. VOLUME uses the data-deck output from Program DIFFERENCE as its input. The program first determines an average value of depth change for each fifty-foot grid square by averaging the depth changes given at the four corners of each square. The average depth change was then multiplied by the area of the grid square to obtain the volume change between surveys for that grid square. The program concludes by adding all of the individual volume changes in the area of study to give a net volume change in the harbor for the period between the surveys.

### 3. Long-Term Bottom Changes

Long-term trends of shoaling and erosion in different parts of the harbor, and also the standard deviation of the water depth about the trend, were obtained through the use of Program STATISTIC. Program STATISTIC plotted water depth versus survey dates for each grid point selected. A least-squares regression line was fitted through the plotted water depths. The slope of the resulting regression line gives a measure of long-term rate of shoaling or erosion at a specific point. The program then goes on to compute the standard deviation of the water depth from this regression line at each point on the grid. The standard deviation computed in this manner gives a measure of the variability of each survey at the various grid points.

For this study 44 grid points located on a 250-foot spacing were chosen to represent the area of study in Monterey Harbor. The location of these 44 points and the resulting contours of all trends and standard deviations computed may be seen in Figures 8 - 11. Appendix C contains the graphs of each of the 44 grid points, and an explanation of the information found on each graph.

## C. HYDROGRAPHIC SURVEY CONDUCTED IN JANUARY 1969

On January 22 and 29, 1969 the final hydrographic survey used in this study was conducted. This section reviews the equipment used in making the survey, the methods of fixing position, and the construction of the final plotted chart. The survey is shown in Appendix F.

### 1. Equipment Used

The Boston Whaler owned by the Naval Postgraduate School was used for the survey. This boat has a draft of 7 inches with two operators on board and was extremely useful for surveying in very shallow depths adjacent to the rocky shoreline and the beach.

Water depths were recorded using an Apelco Portable Recording Depth Indicator (Model MR-201 B). This instrument gives depth readings simultaneously on a lighted scale and on electrically sensitive chart paper. The accuracy of the depth recorder in depths less than 80 feet is specified by the manufacturer to be one percent. In order to be certain that the recorder remained calibrated throughout the survey frequent bar checks were made. The bar checks consisted of lowering a 3-foot metal bar in a horizontal position to pre-measured depths below the transducer. The results of these checks indicate that, with the boat stationary, the accuracy was better than one percent.

The depth transducer was mounted on the transom close to the outboard motor (7½ H.P.). It was found that with the transducer located in this position and the motor operating at idling speed the effects of vibration from the motor and the turbulence caused by the boat's wake were found to be negligible. The survey runs were therefore conducted at idling speed which assured the greatest possible depth accuracy. The latter was further assured by the fact that the harbor was calm on both dates of the survey.

## 2. Position Fixing

The tracks followed in sounding the marina were laid out on a City of Monterey Department of Public Works chart [Drawing No. 1562 (1960)], and the tracks for sounding the remainder of the harbor and the adjacent bay were laid out on a Corps of Engineers chart [Drawing No. 6-2-30 (1963)]. These were the latest charts available for the harbor. Positioning of the survey lines inside the marina is considered to be accurate to within one foot since many check points were available. The tracks followed in the open harbor area are considered to be accurate to within five feet. While there are not as many check points in the outer harbor area, it will be noted in the survey shown in Appendix F that where the track lines crossed one another the depths recorded at these crossings are in close agreement.

## 3. Depth Correction and Chart Construction

Upon completion of the field survey, a correction was applied to the depth record to account for the depth of the transducer below the water surface. The correction amounted to seven inches when two operators were in the boat and five inches if only one operator was aboard. The depth data were then reduced to the Mean Lower Low Water datum using tide records from the Standard Recording Tide Gage maintained on Wharf 2 by the Naval Postgraduate School. Depths at intervals along each track were then plotted on a base chart of scale 1" = 100'.

The base chart used was the Corps of Engineers Drawing No. 6-2-30. The shoreline placed on the chart is the Mean Lower Low Water shoreline obtained partially from the survey and partially from an aerial photograph (Figure 1) taken on February 10, 1969 by Commander Claude F. Giles of the Naval Postgraduate School. The shoreline in the



aerial photograph was corrected for the tide and beach slope to get the Mean Lower Low Water shoreline.

### III. BOTTOM CHANGES OBSERVED

Analysis of the bottom changes that occurred in Monterey Harbor from 1932 to 1969 was made using the fifteen surveys listed in Table II. These surveys are too numerous to be presented in the text and may be found in Appendix A. The objectives were to examine the surveys chronologically to determine the locations and amounts of change that have occurred in the bottom, and to examine possible causes of the changes observed. An additional objective was to determine whether or not seasonal changes occur in the bottom by comparing the surveys during selected months of the year. This latter method of comparison did not give conclusive results and therefore will not be illustrated.

#### A. HISTORICAL BOTTOM CHANGES

##### 1. Comparison of Surveys

Sixteen survey comparisons were made and these are listed in Table III. Charts showing the depth changes between the surveys listed are presented in Appendix B because of the large number involved. Examination of the depth-change charts indicates that significant changes occurred in the harbor from survey to survey during the period from 1932 to 1969. The following general observations may be made when looking at Survey Comparisons 1 through 14. There appears to be four areas of distinctive bottom activity within the harbor. Two of these areas are located in the nearshore zone, the third area is located in the lee of and directly adjacent to the Coast Guard Breakwater, and the final area is the central outer harbor.

The first nearshore area to be discussed includes the beach and shallow-water zone between Wharf 1 and Wharf 2. This beach area experiences large reversals of accretion and erosion and is continually

TABLE III

## SURVEY COMPARISONS

<u>Survey Comparison</u>	<u>Survey Compared</u>	<u>Survey Dates</u>	<u>Number of Months Between Surveys</u>
1	1-2	AUG 32 - MAR 34	19
2	2-3	MAR 34 - JUL 35	16
3	3-4	JUL 35 - OCT 35	3
4	4-5	OCT 35 - SEP 37	23
5	5-6	SEP 37 - JUL 38	10
6	6-7	JUL 38 - DEC 45	88
7	7-8	DEC 45 - JAN 47	14
8	8-9	JAN 47 - FEB 48	11
9	9-10	FEB 48 - JUN 49	16
10	10-11	JUN 49 - SEP 51	27
11	11-12	SEP 51 - MAR 52	6
12	12-13	MAR 52 - AUG 54	29
13	13-14	AUG 54 - AUG 63	108
14	14-15	AUG 63 - JAN 69	65
15	1-15	AUG 32 - JAN 69	436
16	8-15	JAN 47 - JAN 69	264

changing. Survey Comparisons 1, 2, 4, 5, and 6 indicate periods during which the predominant bottom change in this area was accretion. Survey Comparisons 4 and 6 are especially noteworthy in that the amount of shoaling is very large, with the values of fill reaching 10.7 and 10.6 feet, respectively. Survey Comparisons 3, 7, 10, 11, and 14 all indicate a predominance of erosion in the beach area, with the notable comparisons being 3, 7, and 14 with depths of cutting of 8.0, 10.8, and 8.2 feet, respectively. The remaining Survey Comparisons 8, 9, 12, and 13 exhibit both shoaling and erosion. Survey Comparison 7 is particularly interesting because it shows extensive erosion of the nearshore zone with concurrent accretion on the beach. Local onshore-offshore exchange of sand between surveys is exhibited on several of the other comparison charts.

The second nearshore area is the rocky coastline from Wharf 1 to the Coast Guard Breakwater, extending out into the harbor 500-700 feet. The bottom changes there exhibit a pattern of alternating patches of accretion and erosion. The patches are highly irregular and suggest local exchange of sand along the shoreline rather than onshore-offshore exchange. The amounts of erosion and accretion for the most part vary in all survey comparisons between a maximum cut of 6.8 feet and a maximum fill of 7.4 feet, exceptions to this being Survey Comparisons 6 and 12 which show fills of 11.0 and 8.5 feet, respectively.

The third area noted is the narrow zone adjacent to the Coast Guard Breakwater. This zone has also experienced alternating accretion and erosion with time. Survey Comparisons of particular interest concerning this area are 1, 4, 5, 10, and 14, which reveal shoaling on the inside of the breakwater. These comparisons, particularly Comparison 14, suggest that an occasional influx of sand into the harbor may

take place around the end of the breakwater from the small beach on the seaward side. Comparisons 2, 3, 6, 9, and 12 primarily indicate erosion. The remaining comparisons show either small patchy areas of erosion and shoaling or else a lack of activity.

The final area is the central outer harbor, which has remained relatively inactive throughout the 36.6 year period covered by the study. This investigator has made numerous Scuba dives in this area over the period from January 1967 to February 1969 and has found the bottom to be primarily very fine sand or silt with some rock outcrops in the area adjacent to the marina entrance (Figure 4). It was also noted during these dives that coarse litter on the bottom remained virtually unchanged with respect to sediment accumulation during this period. Personal consultations with members of the City of Monterey Harbor Maintenance Division indicate that the same observation has been made by divers since at least 1945.

The two additional survey comparisons analyzed are Survey Comparison 15 which covers the entire period of the study and Survey Comparison 16 which covers the period from 1947 to the present. The latter comparison was made in light of the large discontinuity noted in the volume-change graph (Figure 12), which will be discussed later in this chapter.

Survey Comparison 15 indicates a long-term trend in the harbor toward shoaling everywhere with the exception of two areas which indicate no change. The latter are the central harbor area in the vicinity of the frontal wall and Wharf 2, and the area just off the rocky coastline to the north of Wharf 1. This latter area points out a limitation in the use of these chart comparisons in that this area was indeed



active over the entire span of the study as shown by Comparisons 1 through 14.

Survey Comparison 16 generally shows accretion, although a large area of erosion is indicated in the beach and shallow-water area between Wharves 1 and 2, and smaller areas of erosion may be noted along the rocky shoreline between Wharf 1 and the Coast Guard Breakwater. Again it should be kept in mind that the amount of change shown at any given location in the harbor gives the depth difference between two specific surveys and does not necessarily represent the long-term trend at that point.

## 2. Statistical Analysis

Examination of the survey comparison charts (1-14) over the period 1932-1969 suggests that, although the bottom charts generally show alternating periods of accretion and erosion at most locations in the harbor, the mean change over the period was that of accretion. In order to verify this observation, it was decided to determine the long-term bottom trend throughout the harbor. It was stated earlier that at 44 points in the harbor on a 250-foot grid values of the mean rate of depth change and standard deviation of the depth over a period of years were determined and are contoured in Figures 8-11.

The information contained in these figures will be described in three parts. The first part will present regression-line data computed for all surveys from 1932 to 1969. Because a marked discontinuity in bottom depths in the shallow parts of the harbor occurred between the surveys of 1938 and 1947 (discussed in Section 3 below), a second regression line was fitted to the survey points covering the period from 1947 to 1969. The results of this analysis are treated in the second part.

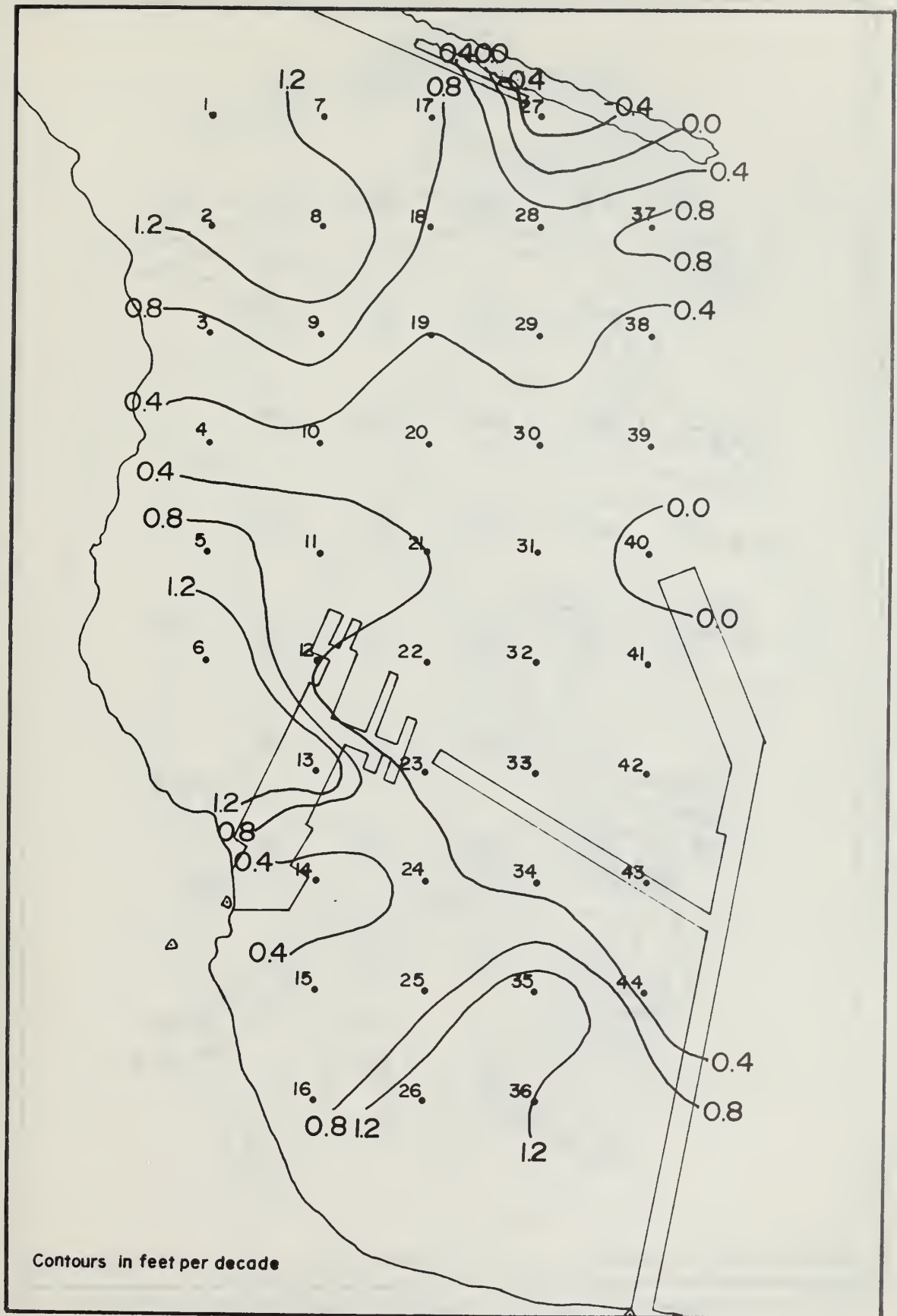


Figure 8. Bottom Trends 1932 - 1969



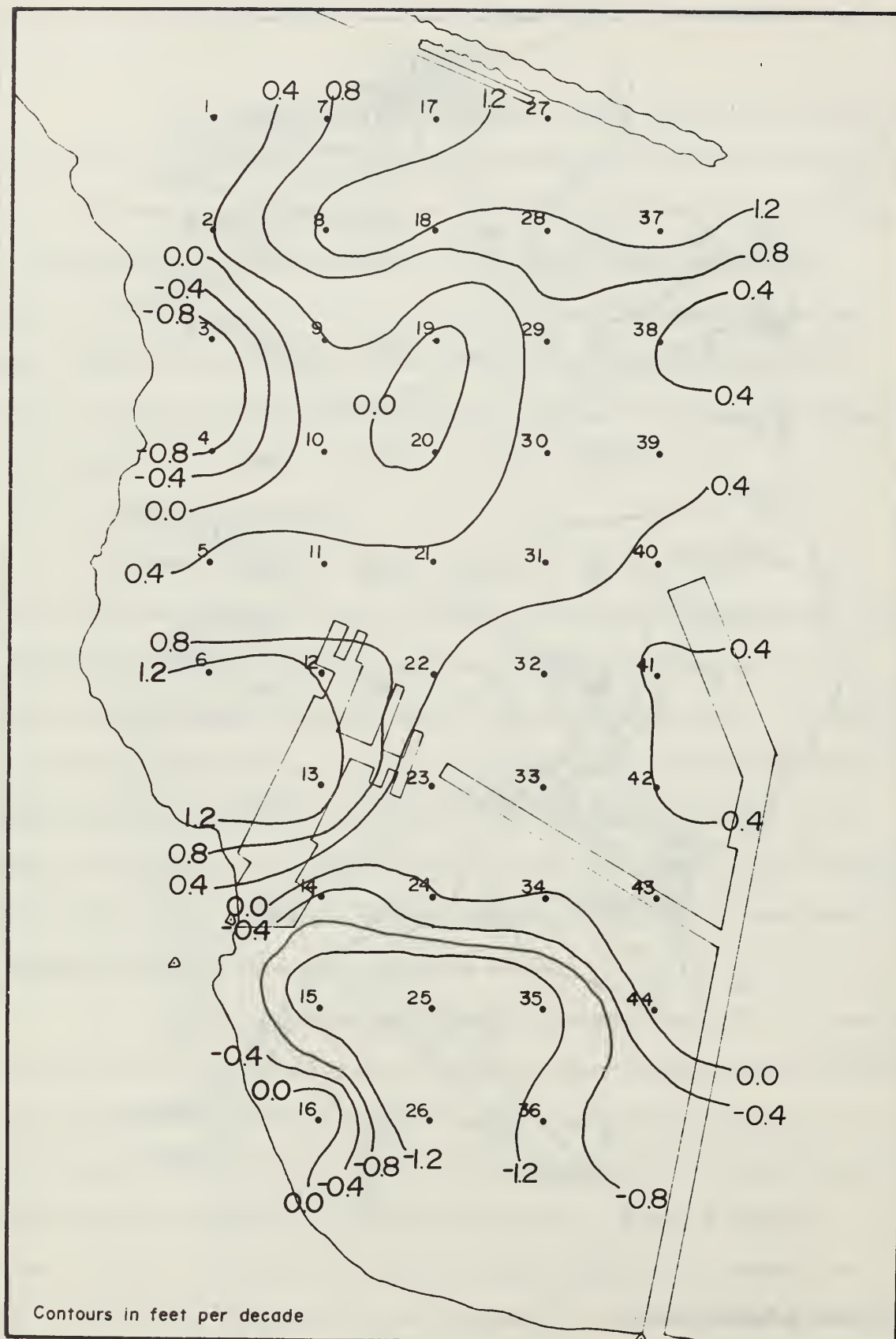


Figure 9. Bottom Trends 1947-1969

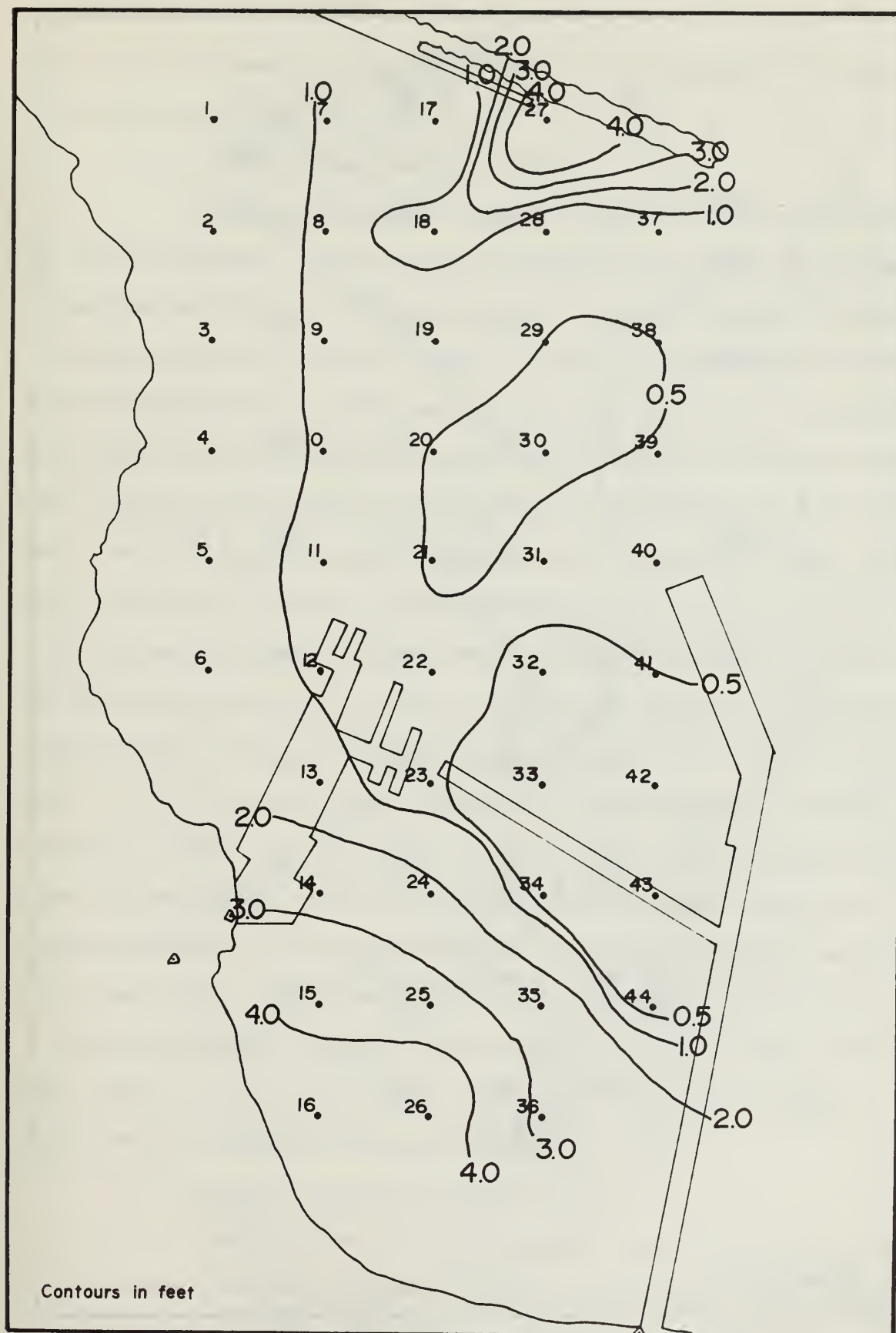


Figure 10. Standard Deviation of Depth 1932-1969

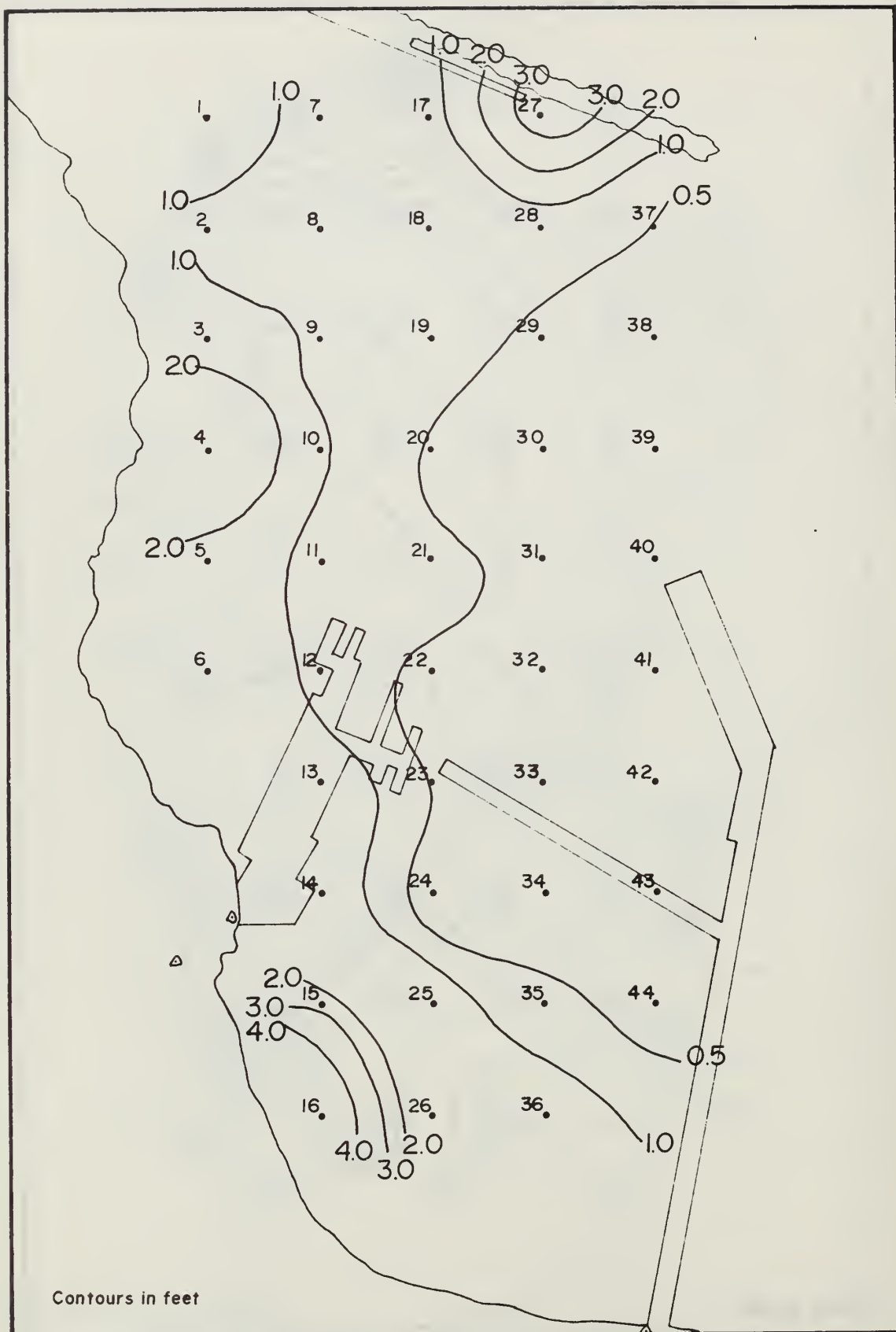


Figure II. Standard Deviation of Depth 1947-1969

The final part examines the plotted contours of the standard deviations covering both periods.

a. Bottom Trends Between 1932-1969

Figure 8 shows the contours of the mean bottom change over the period 1932-1969. The mean rate of change of the bottom is expressed in feet per decade. The harbor bottom shows a long-term trend of shoaling everywhere except for two small areas, one near the outer tip of the Coast Guard Breakwater and the other near the outer end of Wharf 2. In examining Figure 8, the four general areas of activity within the harbor which were revealed by the contoured change charts described above may be recognized. Specifically, these are the shallow-water zone between Wharf 1 and Wharf 2, the area along the rocky coastline, the area adjacent to the Coast Guard Breakwater, and the outer harbor. In the marina beach area shoaling has occurred at a rate of 0.7 foot or greater per decade, giving a mean volume rate of increase per decade of approximately 2,000 cubic feet or greater per 50-foot grid square. When this is multiplied by the number of 50-foot grid squares in the beach area this becomes a significant bottom trend. Likewise, the trend in the northern corner of the harbor and along the majority of the rocky coast line is 0.8 foot or greater per decade over a larger area. Thus, the overall rate of volume increase in this area is also significant. The area of little bottom activity in the central outer harbor is seen to be shoaling at a rate of 0.2 foot or less per decade, and is an unexpectedly stable area.

b. Bottom Trends Between 1947-1969

Figure 9 shows the contours of the mean bottom change over the period 1947 to 1969. Examination of the figure shows a large area of erosion in the shallow-water zone between Wharves 1 and 2 with a trend of

-1.2 foot per decade. There is also a second area of erosion located in the northwestern corner of the harbor on the rocky coast which has a rate of -0.8 foot per decade. Areas of significant shoaling are the nearshore zone along the rocky coast just to the west of Wharf 1, the lee of the outer portion of the Coast Guard Breakwater, and a strip extending from the latter area across the harbor to Wharf 1. In the outer harbor accretion occurred at a slow rate, although around the outer end of Wharf 2 somewhat more rapid filling may be noted.

The long-term bottom-change trends shown in Figure 8 and Figure 9 are seen to be quite different upon comparison. Where Figure 8 shows general accretion, Figure 9 shows some areas of significant erosion. In both, however, the two areas of most active change are the beach and nearshore zone between the two wharves and the rocky coast in the vicinity of the rubble sand trap. Secondarily active areas are the area off the rocky shoreline in the vicinity of the breakwater and inside of the end of the breakwater. The stable outer harbor area experienced slow accretion during both periods.

#### c. Standard Deviation of the Depth

Figures 10 and 11 show the standard deviation of the depth from the long-term depth trends throughout the harbor for the periods 1932-1969 and 1947-1969, respectively. Both figures show that the variability of the bottom is large in the nearshore area, particularly off the sand beach between Wharf 1 and Wharf 2, and also near the outer end of the breakwater. This is indicative of active shifting of sediments in these areas over the period of the surveys. Very little variability in depth with time is noted in the offshore area beyond the 14-foot contour in the beach area and the 18-foot contour off the rocky coastline, which indicates a stable bottom.



When Figures 10 and 11 are compared the two patterns of bottom depth variation are very similar, although the magnitude of the 1947-1969 deviations were smaller. A comparison of the deviation maps with the depth-trend maps reveals that, in general, areas of most rapid long-term accretion or erosion are also areas of the largest depth deviation from the long-term trend.

In the areas of stable bottom in the outer harbor the standard deviation varied from 0.5 to 0.25 foot, indicating that the accuracy of the series of surveys conducted was very good.

### 3. Volume-Change Computations

The change in sediment volume in the harbor occurring between successive surveys, and between selected surveys, was computed and the results are tabulated in Table IV. Because these volume changes occurred over variable survey intervals, the volume changes were converted into annual rates of net shoaling or erosion so that the volume changes can be compared on the same rate basis. The volume change between two surveys represents an areal integration of the depth changes between the surveys, and provides an overall indication of the change in the harbor.

The 15 surveys do not cover exactly the same area; accordingly, in order to derive volume figures that can be compared, the area was reduced to the largest area common to all surveys. This area is shown in Figure 6. Unfortunately this resulted in eliminating some of the shoreline zone where large volume changes occurred.

It may be noted in the table that the rates have been highly variable and that both accretion and erosion have occurred between surveys. The largest rate, which was registered over the 3-month period

between Survey 3 and Survey 4 (Jul 35 - Oct 35), exceeded 500,000 cubic yards per year.

The actual volume changes between surveys are plotted in Figure 12 in the form of a cumulative volume change with time. This figure shows that: (1) A discontinuity in the trend of the net volume change occurred about 1945; the mean volume change from 1932-1945 was much larger than from 1945-1969. (2) Overall shoaling rates averaged 17,500 cubic yards per year from 1932-1969 and 7,100 cubic yards per year from 1947-1969.

The volume analysis was not carried further, but there are other promising ways of handling these data. One suggestion for further analysis would be to examine the volume changes by grid squares in order to determine changes on a smaller scale or in limited parts of the harbor. Also, the positive and negative volume changes between two surveys could be calculated separately.



TABLE IV

## VOLUME FIGURES FOR COMMON AREA

This table shows the amount of change in volume experienced between surveys and the annual rate derived therefrom. The area of the harbor common to all surveys is shown by the heavy dashed line in Figure 6, and totals 274,186 sq yards. Positive values of change represent net accretion between surveys and negative values represent erosion.

<u>Surveys Compared</u>	<u>Comparison Number</u>	<u>Volume Change Between Surveys (cu yds)</u>	<u>Number of Months</u>	<u>Annual Rate of Change (cu yds/yr)</u>
1-2	1	149,262	19	94,271
2-3	2	21,242	16	15,931
3-4	3	-132,925	3	-531,699
4-5	4	17,393	23	9,075
5-6	5	216,405	10	259,686
6-7	6	458,113	88	62,470
7-8	7	-233,416	14	-200,070
8-9	8	5,873	11	6,406
9-10	9	20,019	16	15,015
10-11	10	76,326	27	33,923
11-12	11	-121,193	6	-242,387
12-13	12	159,713	29	66,088
13-14	13	-83,398	108	-9,266
14-15	14	99,704	65	18,407
1-15	15	649,157	436	17,545
8-15	16	157,038	264	7,138

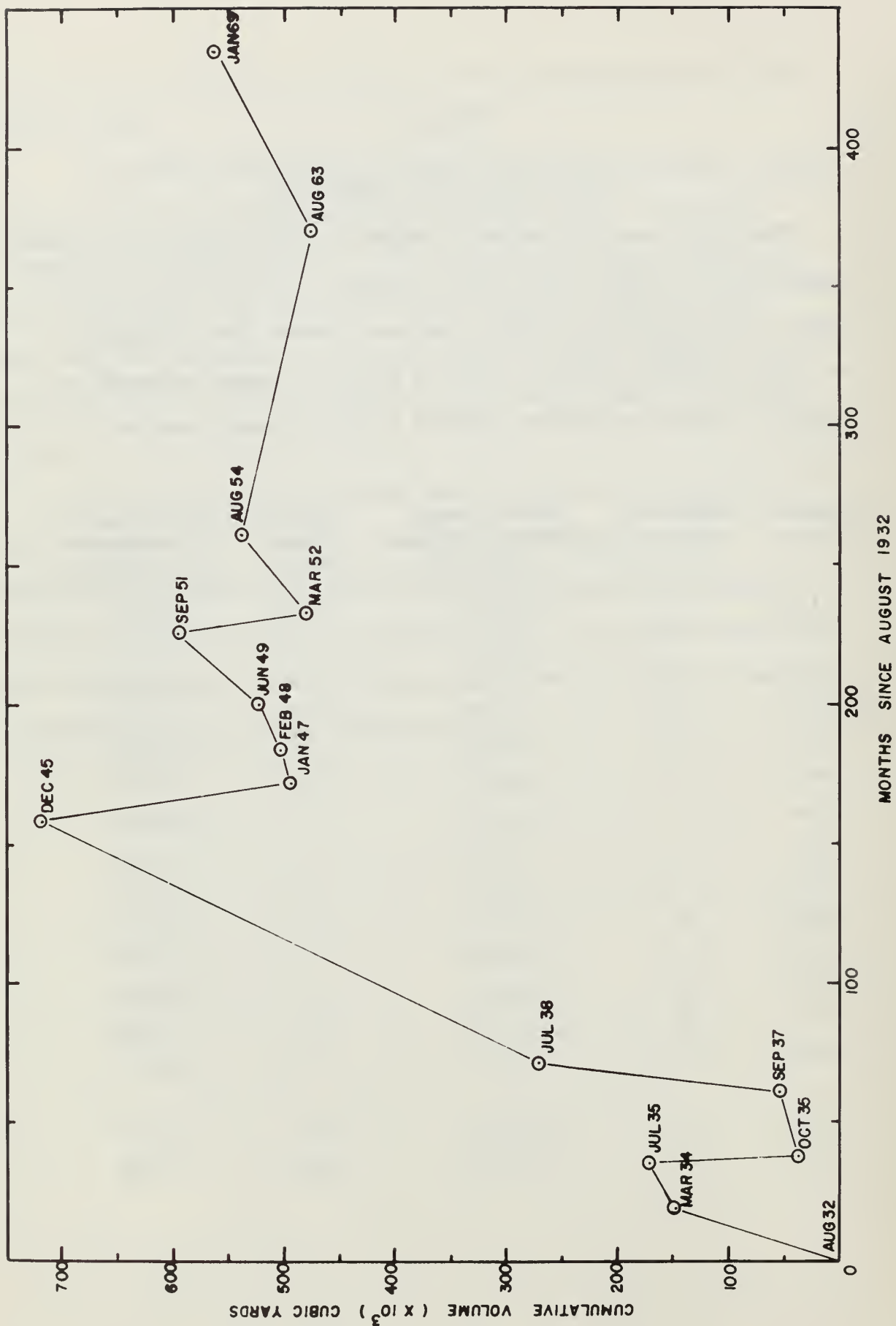


Figure 12. Cumulative Volume vs Time

## B. SEDIMENT REGIME AND THE EFFECT OF HARBOR WORKS

The purpose of this section is to present deductions regarding the sediment regime in the harbor based on the observations presented earlier, and to inquire into the effects of structures and dredging on sedimentation in the harbor.

### 1. Sediment Regime

No attempt has been made to establish a sand budget for the harbor, and the following discussion of the sediment regime therefore represents a series of deductions based upon all available information.

The areas of active bottom change in the harbor have been shown to be the beach and nearshore zones, and the bottom adjacent to the breakwater. These are also the areas of sand bottom. The undisturbed appearance of the mud bottom in the outer harbor indicates that sand does not move across it. Accordingly, it may be deduced that sand movements are restricted to the nearshore zone and the bottom close to the breakwater.

Bottom changes between surveys in these areas can be attributed only to a net gain or loss of sand in the harbor due to exchange with the adjacent beaches, or to local redistribution of sand within the harbor. A net gain or loss may be brought about by littoral drift exchange with Del Monte Beach on the upcoast side of the harbor or by transport around the end of the breakwater by wave currents generated along the seaward face of the breakwater or possibly by tidal currents. Evidence that the latter occurs is given by the location and shape of the sediment accumulation on the inside of the outer end of the breakwater. Examples of this accumulation may be noted in Comparisons 14, 15, and 16, and also by the trend toward shoaling in this area as shown in Figure 9.

Additionally, an increase in depth noted directly off the end of the breakwater is indicative of a scoured area as would be caused by currents moving around the breakwater. It appears improbable, however, that significant transport of sand out of the harbor around the breakwater occurs due to the lack of apparent generating forces in the harbor to produce currents of sufficient strength moving out of the harbor area. With regard to redistribution of sand within the harbor, no clear-cut pattern occurs except in the area between Wharf 1 and Wharf 2 where the beach clearly has experienced general onshore-offshore migration of sand between the shallow-water zone and the beach. However, the changing zones of cut and fill noted off the rocky shoreline suggest that the topography of these zones may be a controlling factor in the manner in which the sediments are redistributed.

It is evident that if sand exchange between the harbor and the adjacent coast is significant, a large net change in the sediment volume of the harbor should be indicated from one survey to another, whereas if the exchange with adjacent beaches is small the net volume change should also be small even though large bottom changes may occur within the harbor. Unfortunately, the fact that the study area does not include the beach backshore means that sand could be redistributed internally within the harbor with no exchange taking place with adjacent areas and still a significant volume change may be registered for the harbor in Table IV.

It is probable that the large volume changes listed in Table IV that occurred prior to construction of the east wall along Wharf 2 are due largely to sand exchange with Del Monte Beach by littoral drift. Upcoast littoral drift, indicated by large negative volumes representing

a net loss of sand from the harbor, is probably caused mainly by a dominance of northwesterly swell which arrive with small upcoast angles of wave incidence. Large positive volumes representing net accretion are probably caused by the occurrence of Bay Wind Storms and by a predominance of long-period southerly swell. Some of the volume change recorded in the figures of Table IV may be due to dredging operations in which sand has ordinarily been dredged from the seaward part of the beach deposit and placed on the beach proper outside the area of the hydrographic surveys. This situation would give an erroneous indication of a net loss of sand from the harbor.

Construction of the bulkhead on Wharf 2 in 1960 cut off the sand exchange with Del Monte Beach, but in spite of this barrier the harbor gained sediment at an approximate annual rate of 18,000 cubic yards over the seven-year period between Surveys 14 and 15. It thus appears that sand flow around the breakwater must account for the bulk of this net accretion. Additional study of the sediment budget for the harbor would be required to test this deduction.

The slow net gain of fine sand and silt that has occurred in the outer harbor over the period of study may be attributed in part to heavy discharge of sediment by the Salinas River (Figure 2) during periods of flooding. This investigator observed that immediately following the period of major floods in January and February 1969 approximately a half inch of fine sediment was deposited on the exposed rock bottom off Del Monte Beach within a quarter mile of the harbor.



## 2. Effect of Harbor Structures

The structures built in Monterey Harbor during the period of the study (Figure 3) appear to have had the following effects on sedimentation.

The Coast Guard Breakwater generally serves to protect the harbor from the north, acts as a trap for any sediments entering the harbor, and induces wave currents in its vicinity. This structure also appears to have caused a slight sand accumulation on the beach on its seaward side.

The east wall prohibits the exchange of sand between the marina and Del Monte Beach. Survey 15 of Appendix A reveals that a small fillet of sand has accumulated against the outside of the wall since it was built nine years ago.

The frontal wall, which is located in the area of stable bottom, has no apparent effect on sedimentation as indicated by the fact that there has been very little accumulation or erosion on either side. This structure contains a tidal-current circulation within the marina, and also protects the beach area between the two wharves from the full force of incident waves.

The Rubble Sand Trap has been virtually useless over the years and is presently considered an eyesore by the City of Monterey. Steps are being taken for its removal.

The Sea Wall and Small Boat Launching Ramp both reduce the movement of sand from the beach area into the southernmost corner of the marina. These structures have replaced the beach in this portion of the marina, thereby eliminating a source of sediment for onshore-offshore exchange.

The two storm drains contribute limited quantities of sediment to the marina area. Indications were noted in various survey comparisons that the large drain located under Wharf 2 is the major source of sediments so derived.

### 3. Effect of Dredging Operations

The major dredging operations are listed in Table I. Generally the effects of dredging have only been of a local nature and have had a limited period of effectiveness. For example, the dredging operation between Wharf 1 and Wharf 2 carried out in 1947 by the Corps of Engineers removed approximately 58,000 cubic yards of sand, of which about 38,000 cubic yards of the spoil was placed on the beach between the two wharves as fill for depleted areas. The Corps of Engineers (1959) estimated that within the 2½ year period following the dredging over 21,000 cubic yards of beach material had been redistributed back to the area of dredging.

The spoil from dredging operations both offshore and in the shallow-water zone (Figure 3) has been placed within the harbor area in apparently every instance, and has been redistributed locally by natural causes. It thus appears that the procedure of retaining the dredge spoil within the harbor area has been in error.

#### IV. RECOMMENDATIONS

The following recommendations are made in light of this study.

##### A. SURVEY TECHNIQUES

Survey techniques in which some improvements are desirable are:

1. All surveys for a particular area should be plotted using the same scale. There should be common grid lines to aid in relating one survey to the next for purposes of computer comparison.
2. The scale most desirable is 1" = 50' for nearshore and harbor surveys. When scales in excess of 1" = 100' are used, too much smoothing of the bottom contours is required and some detail is lost.
3. When surveying an area such as Monterey Harbor, beach portions of the shoreline should be resurveyed each time in order to obtain a record of the shoreline location for survey comparison purposes.
4. Monterey Harbor and other coastal harbors should be surveyed on an annual basis to provide better control of information on the changes occurring.

##### B. FURTHER STUDIES

The following subjects are recommended for further study to better understand the changing nature of Monterey Harbor.

1. A sediment budget for the harbor should be determined.
2. A geological study should be made in the harbor area of the thickness of sediments overlying the bedrock and the location of the contact between the Santa Lucia and Monterey Formations.
3. Computer processing of the hydrographic data in limited areas of the harbor, such as the beach area between Wharves 1 and 2, in order to examine local conditions would provide additional information concerning bottom changes.

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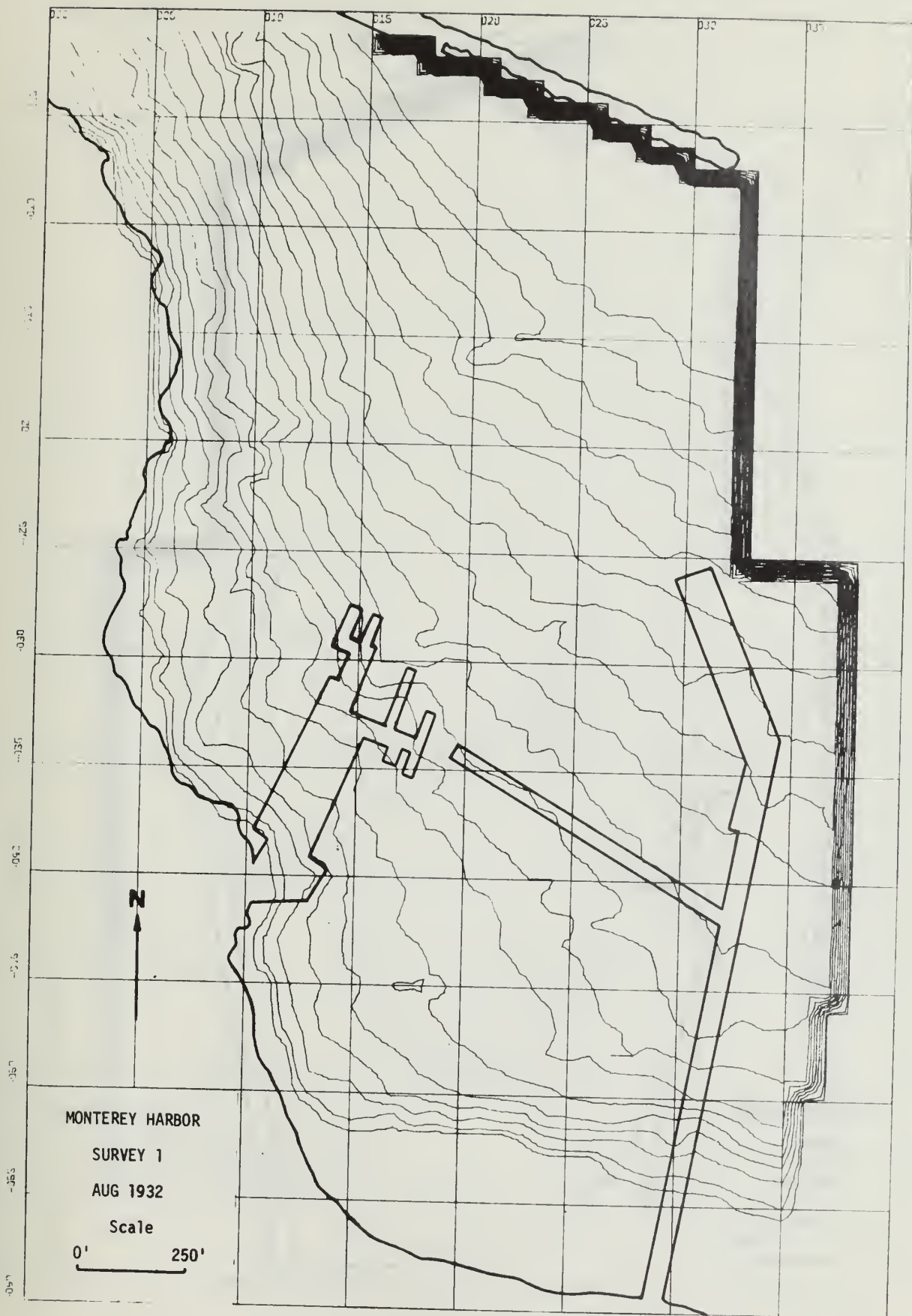
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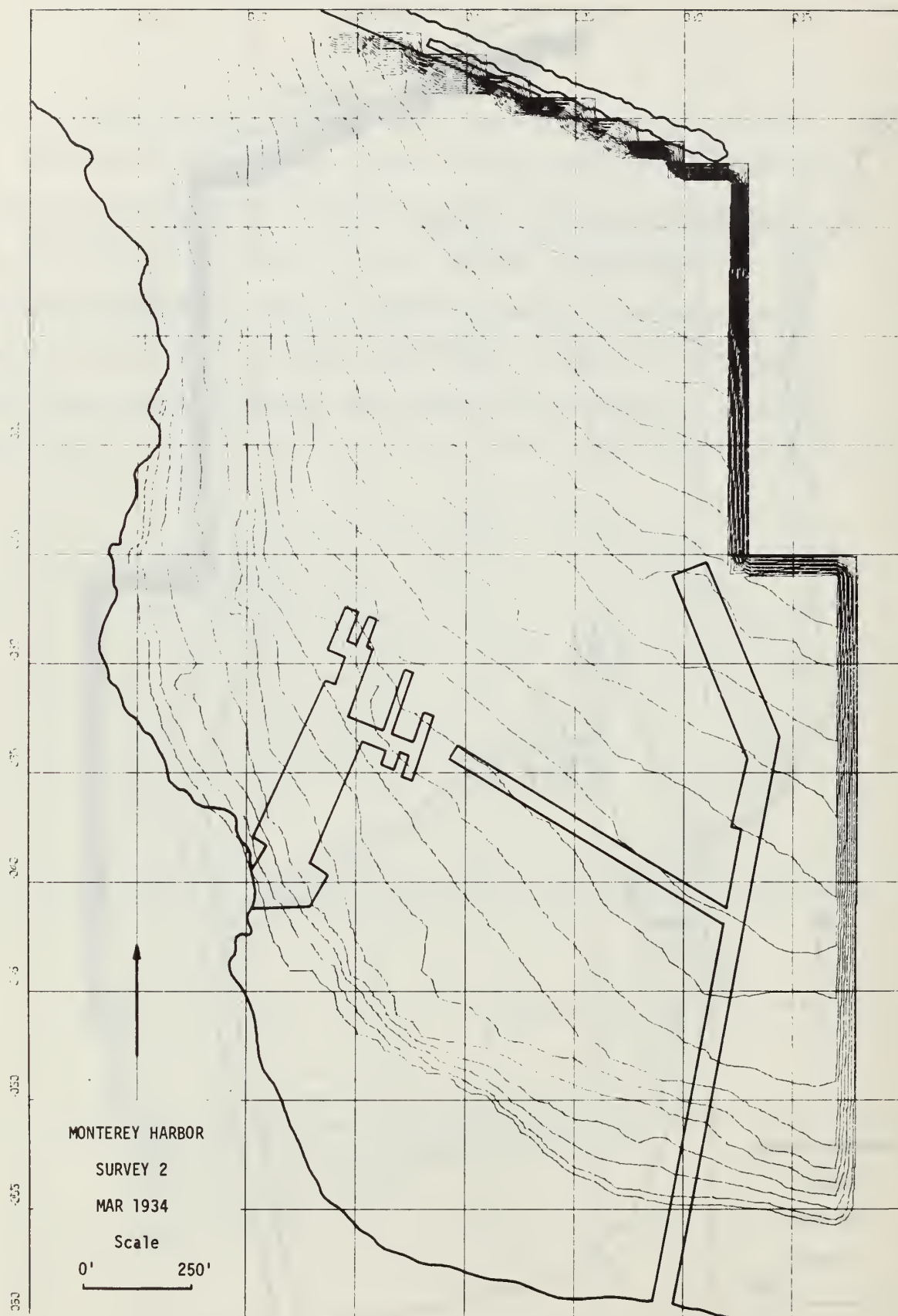
## APPENDIX A

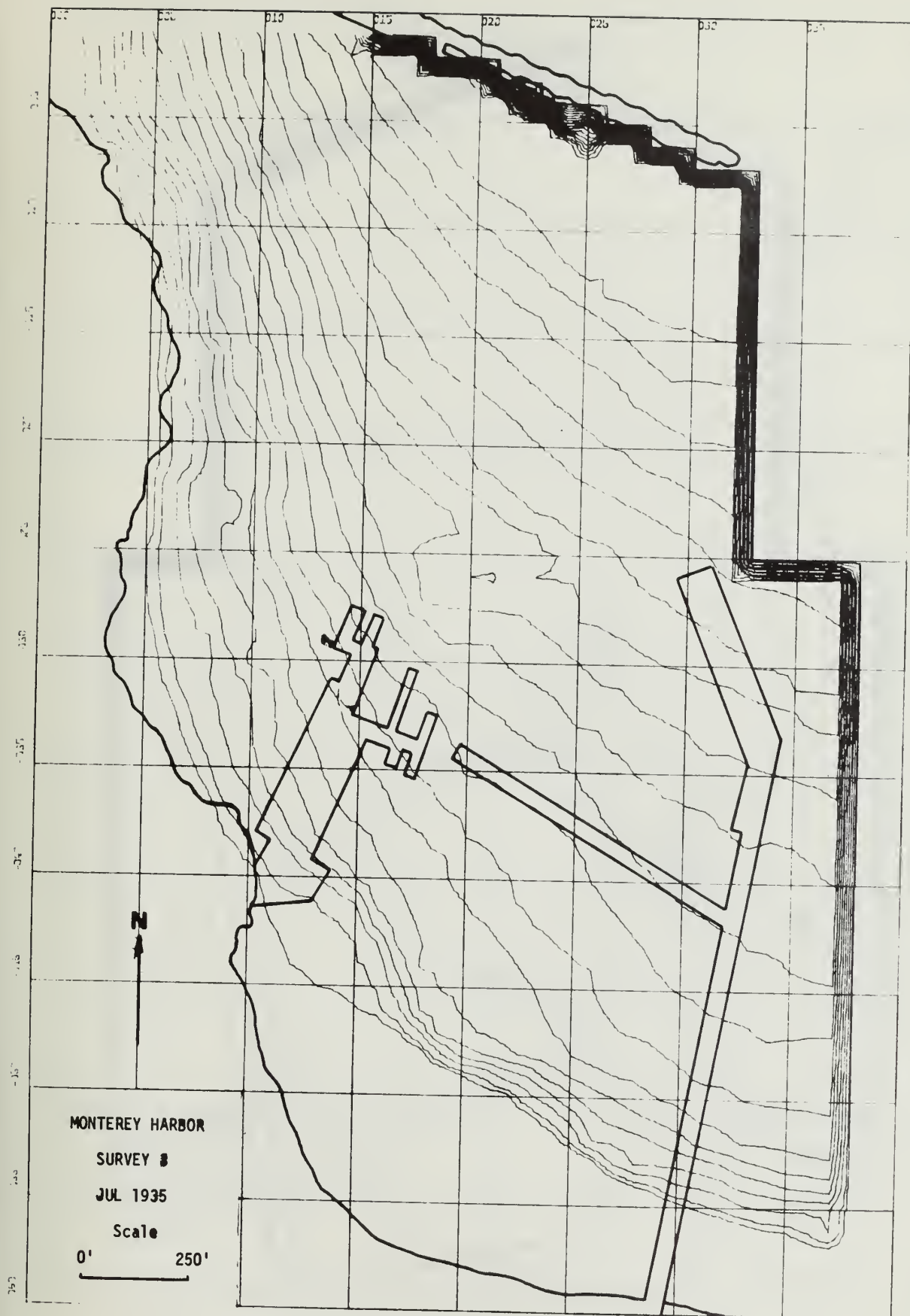
### SURVEYS 1 through 15

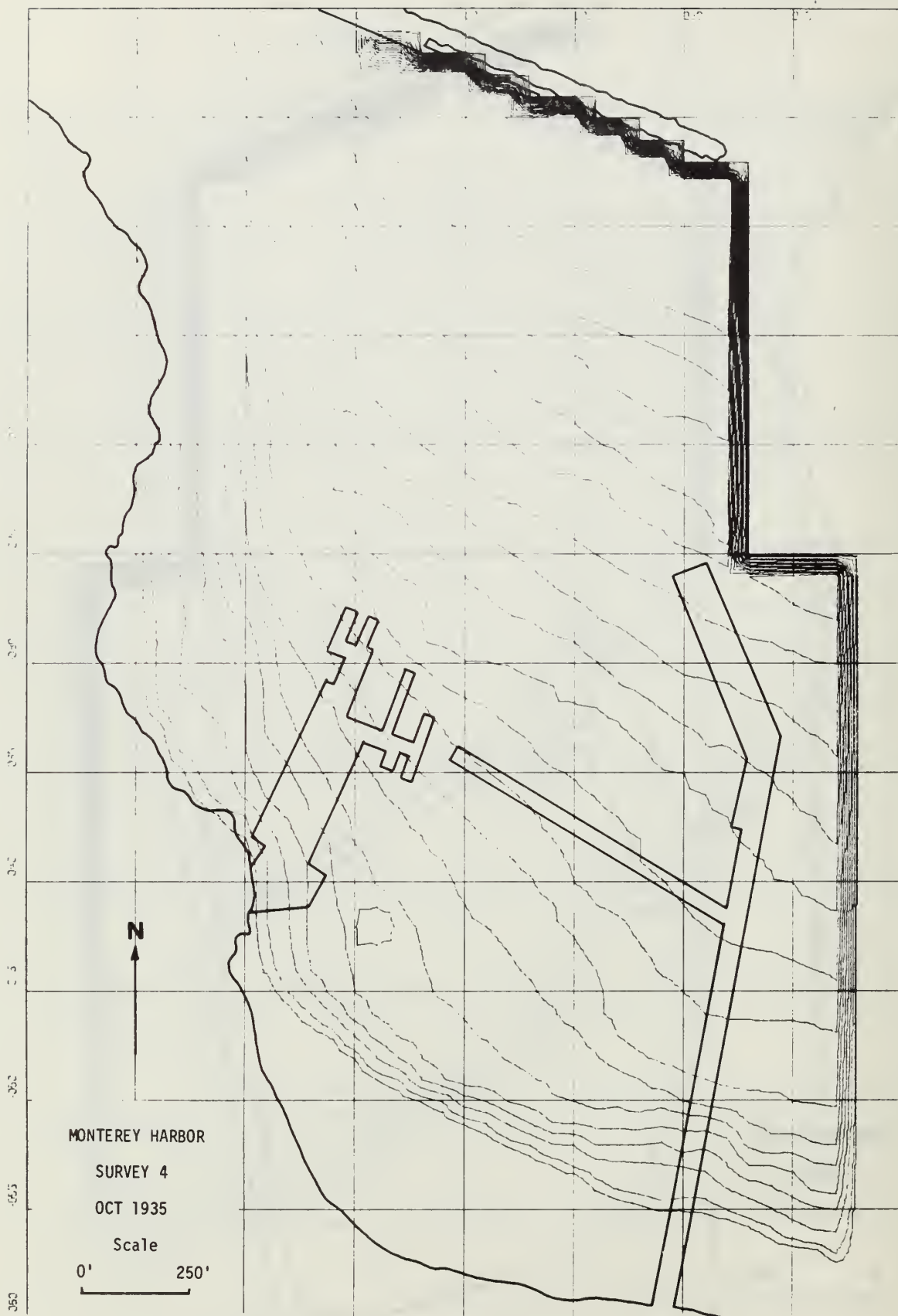
The fifteen hydrographic surveys used for comparison throughout the study are presented. The shoreline on all charts is taken from the 1932 survey. The initial contour adjacent to this shoreline is one foot, followed by a two-foot contour; subsequent contours are at two-foot intervals. The datum is Mean Lower Low Water. The identification and characteristics of the original survey charts are listed in Table II.







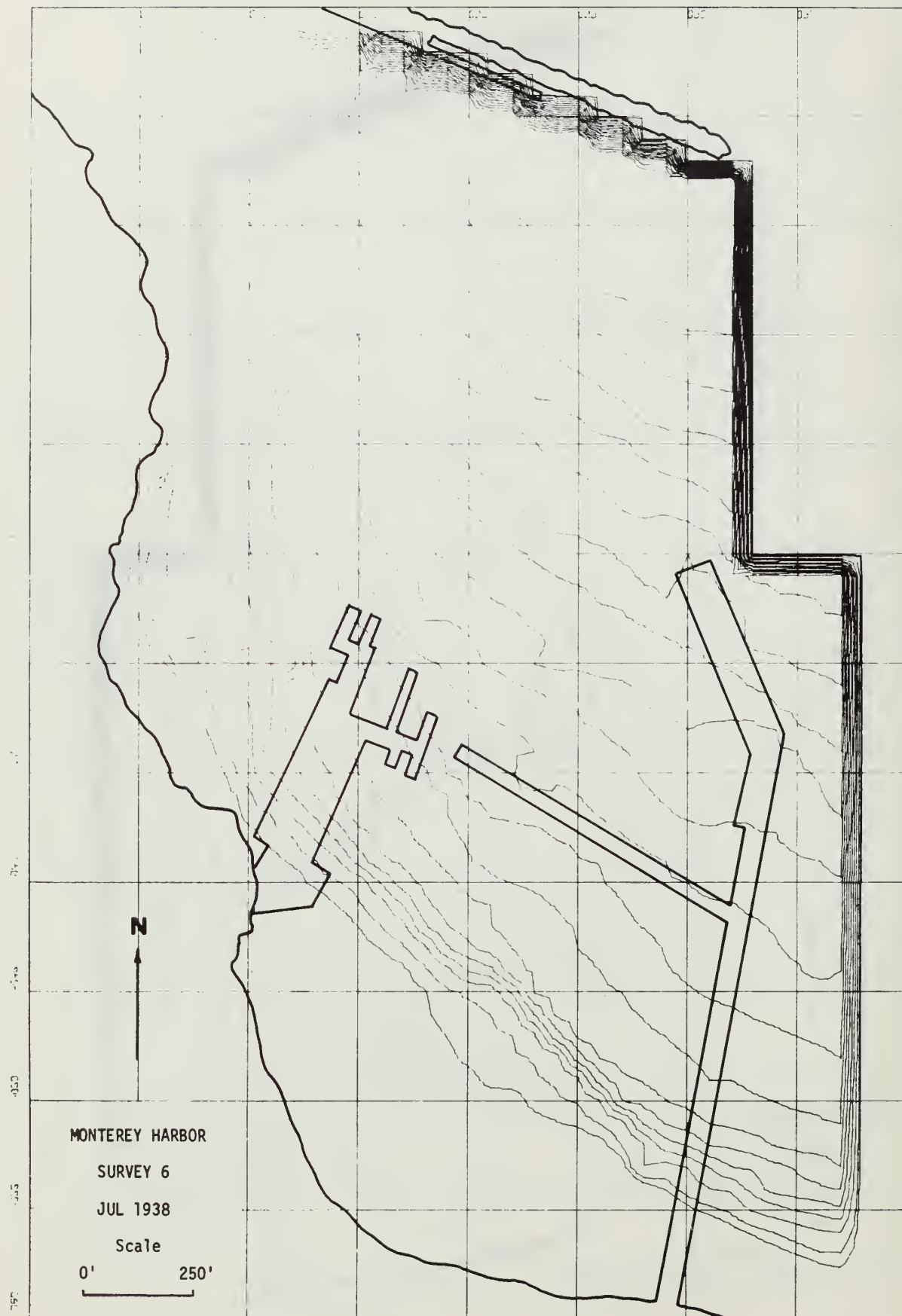


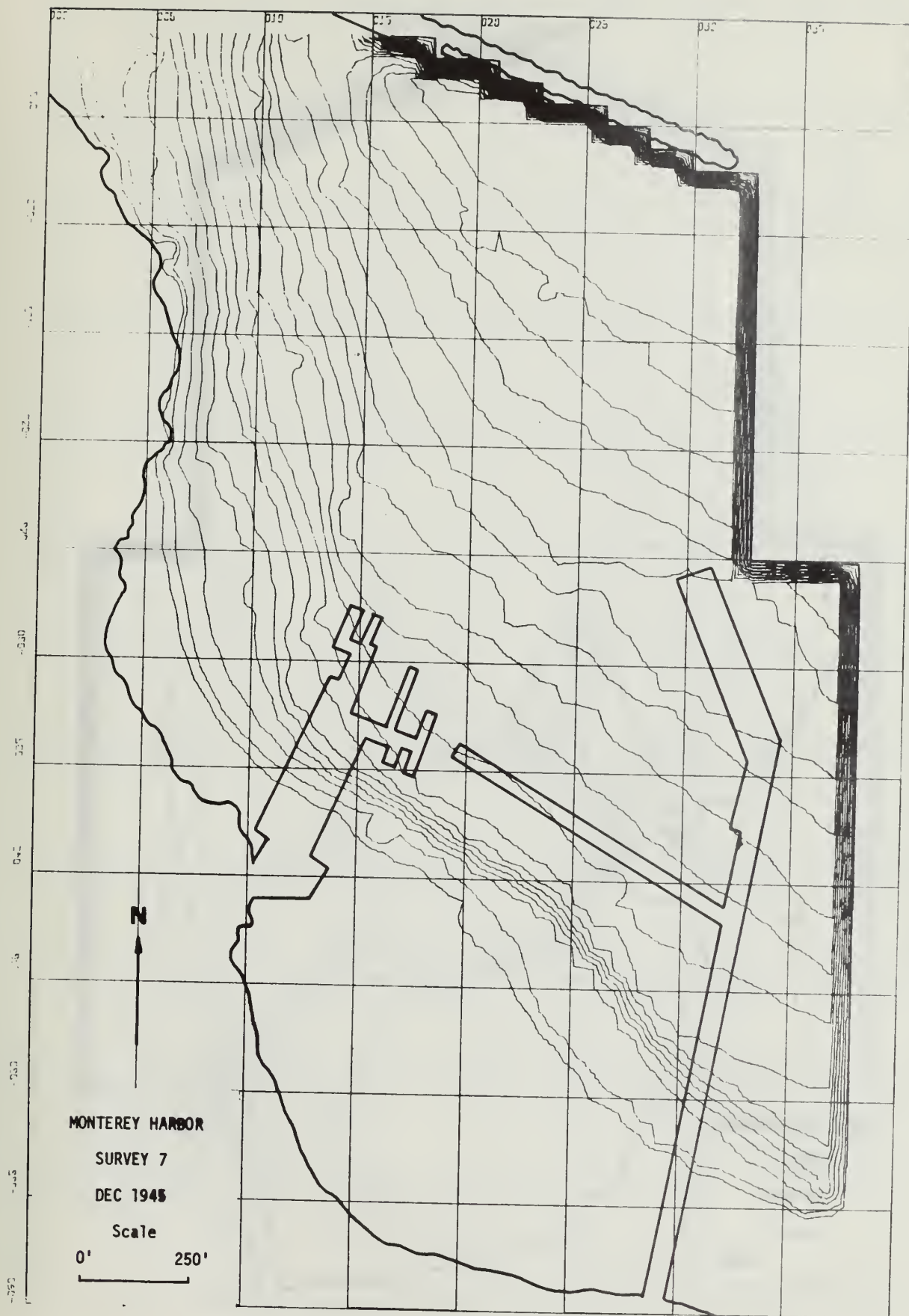


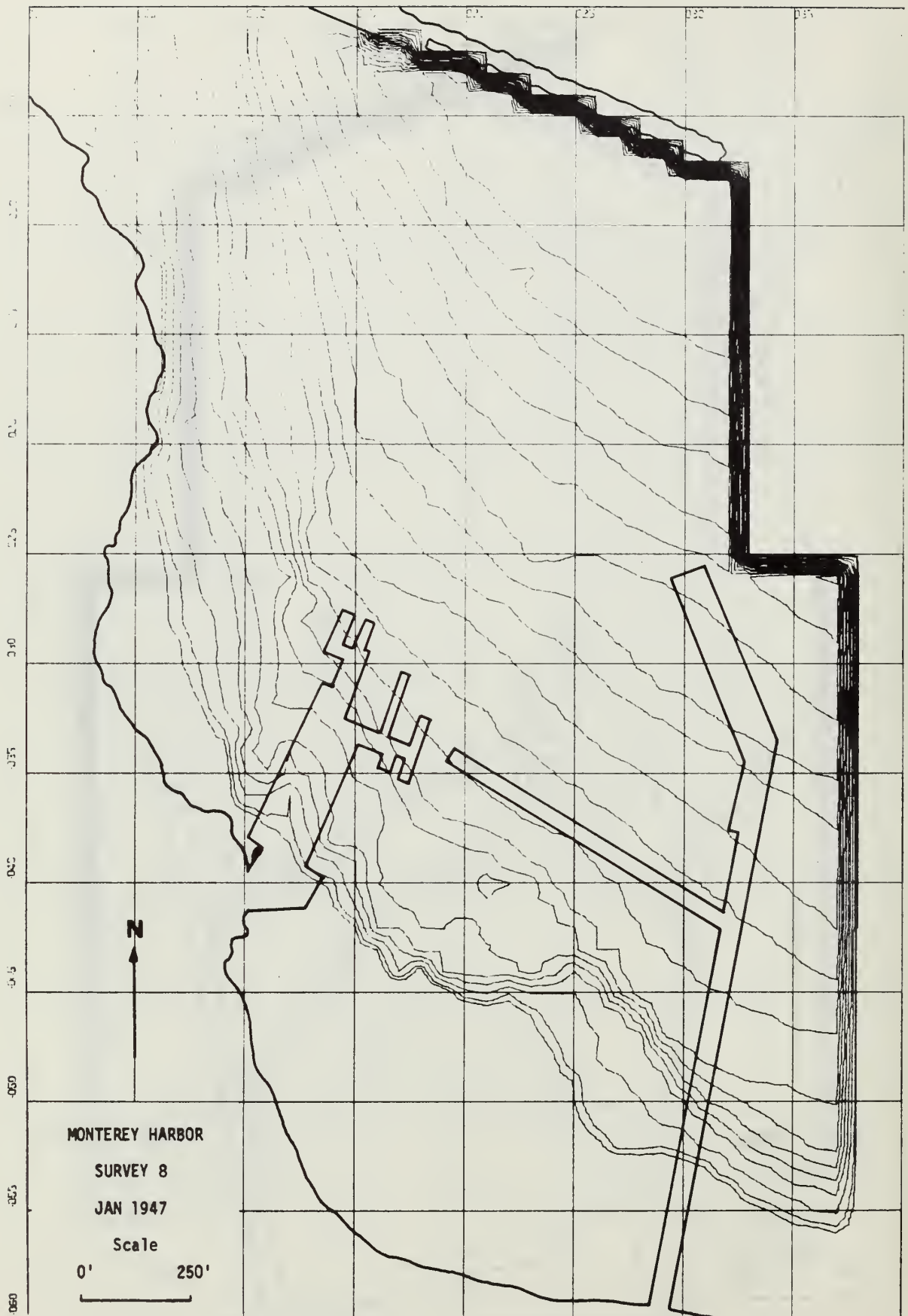


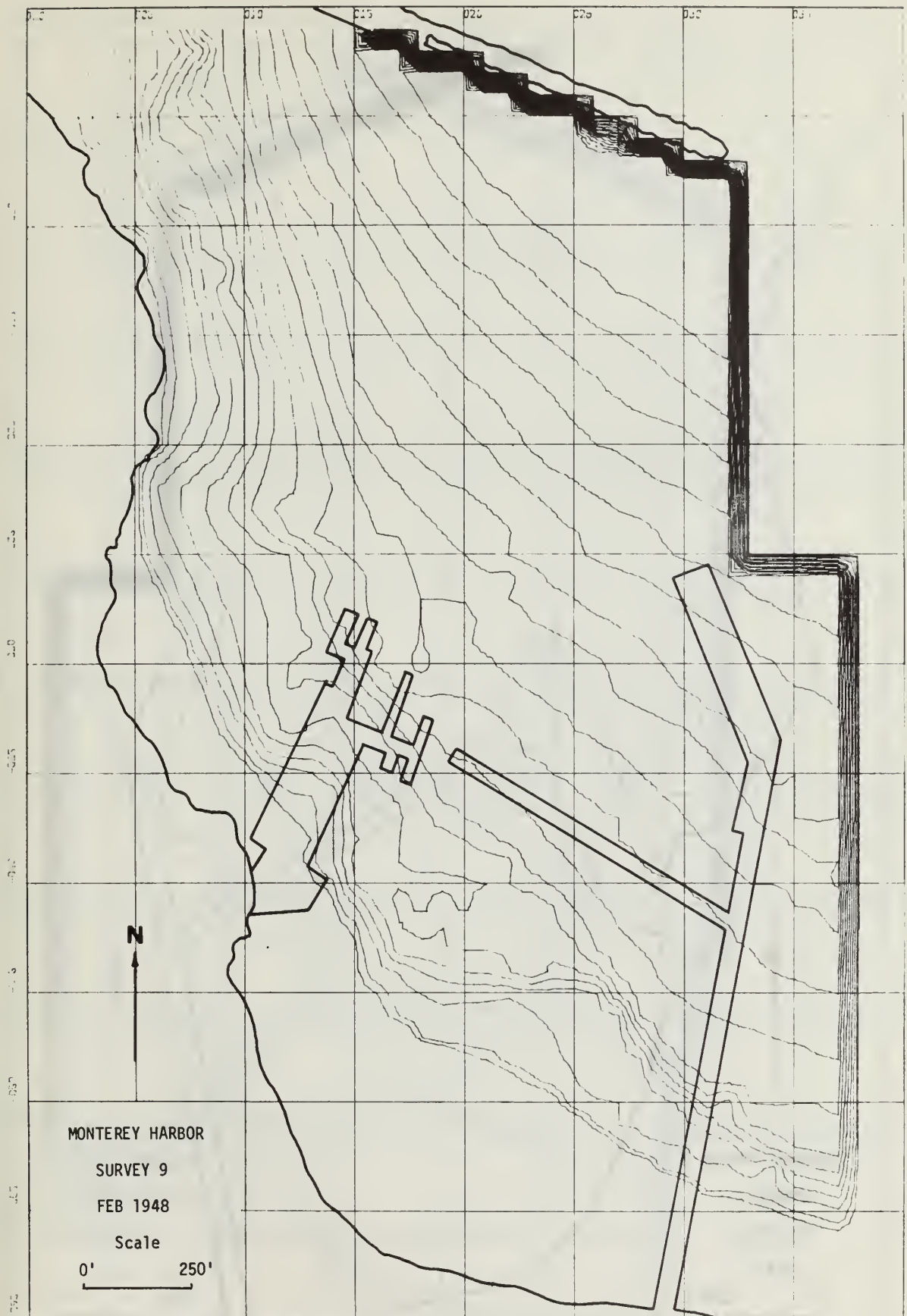




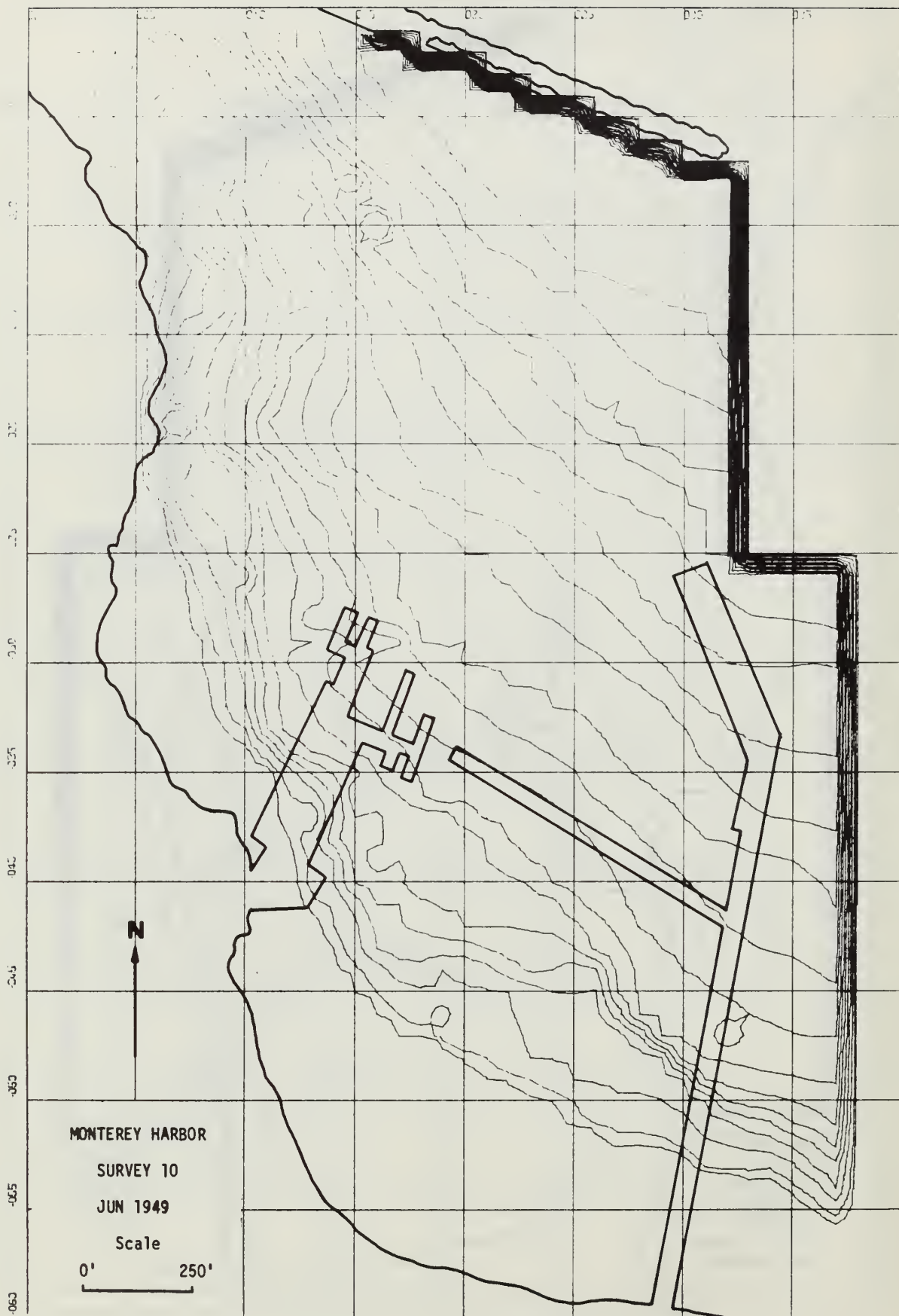




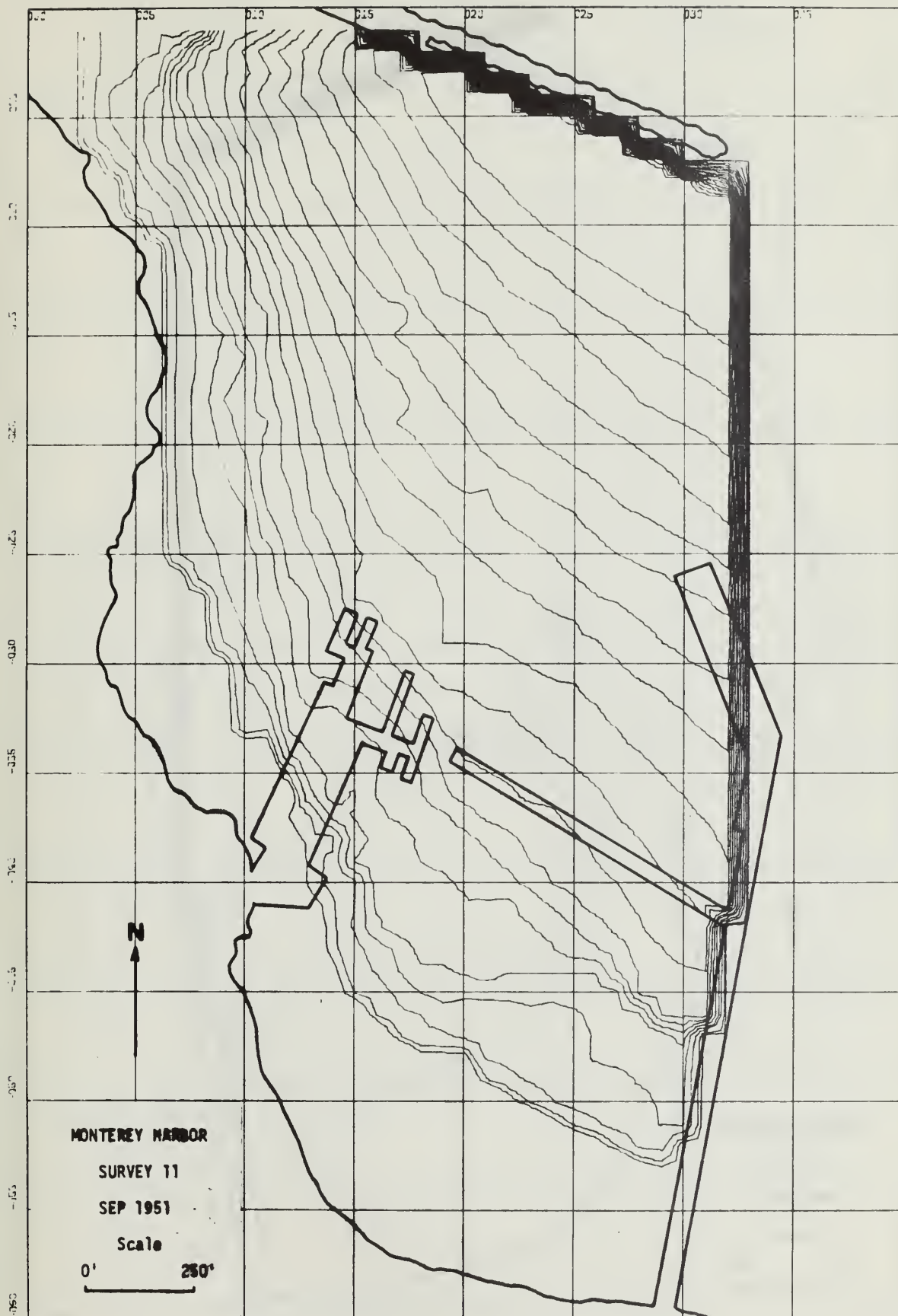


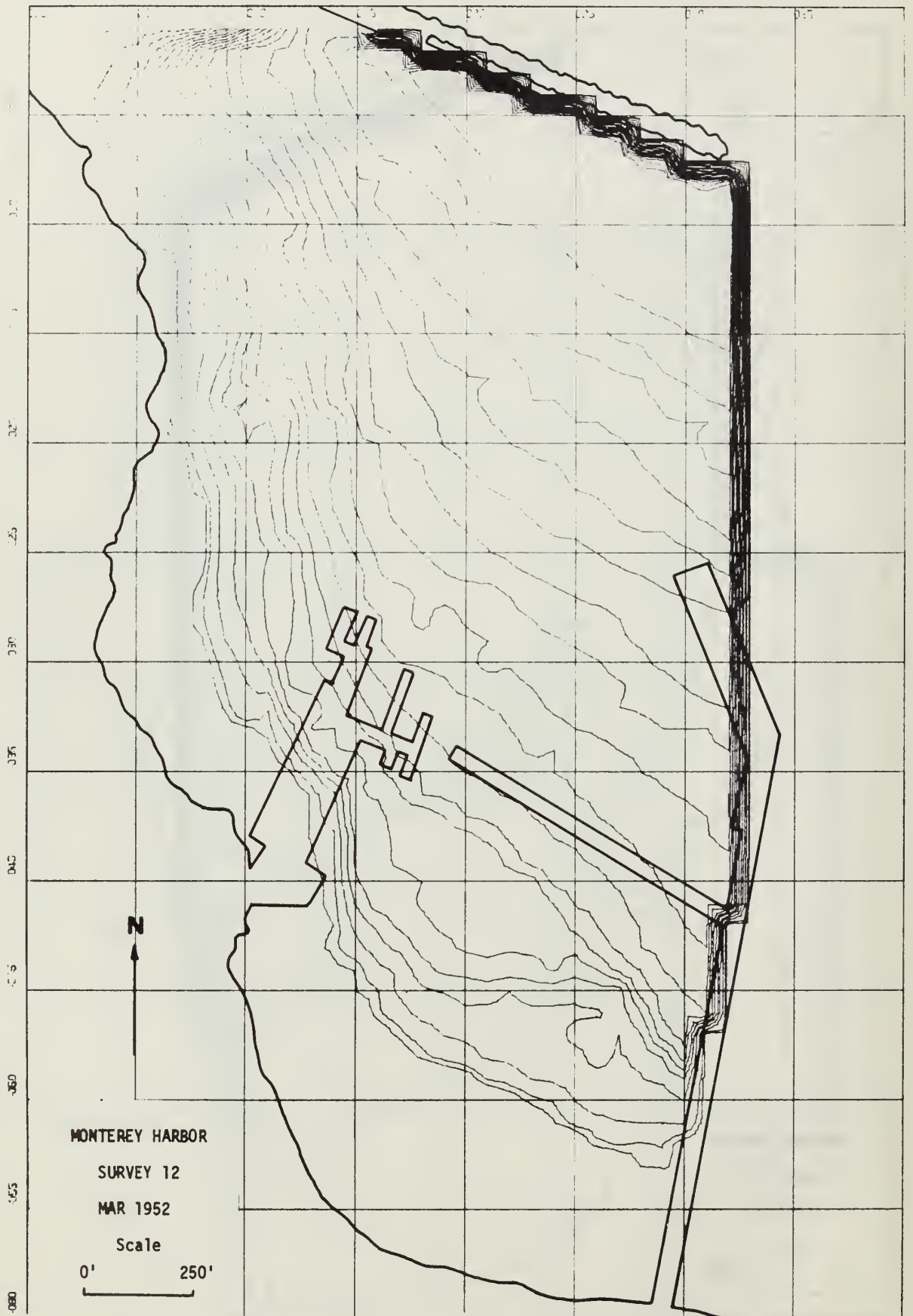


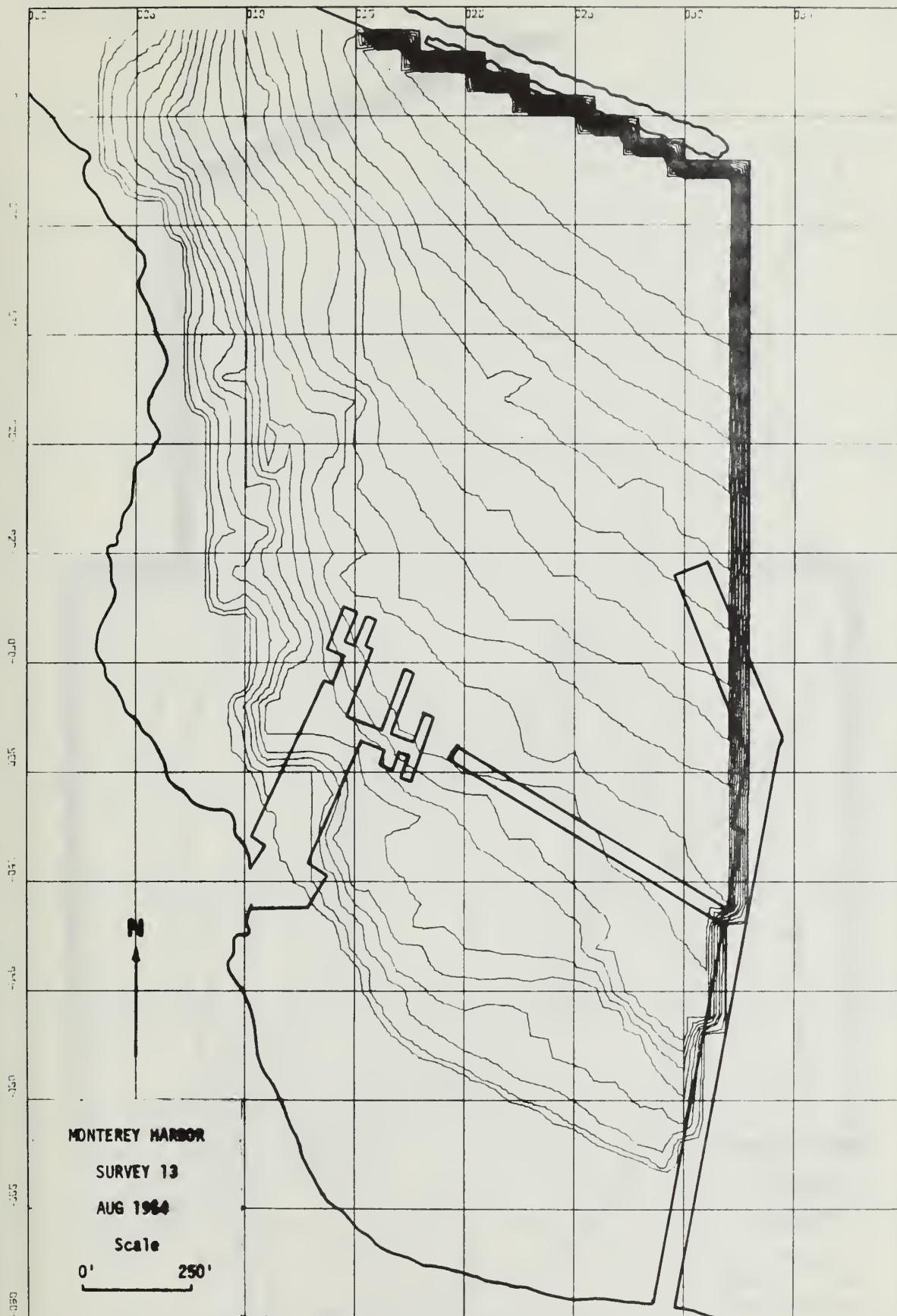


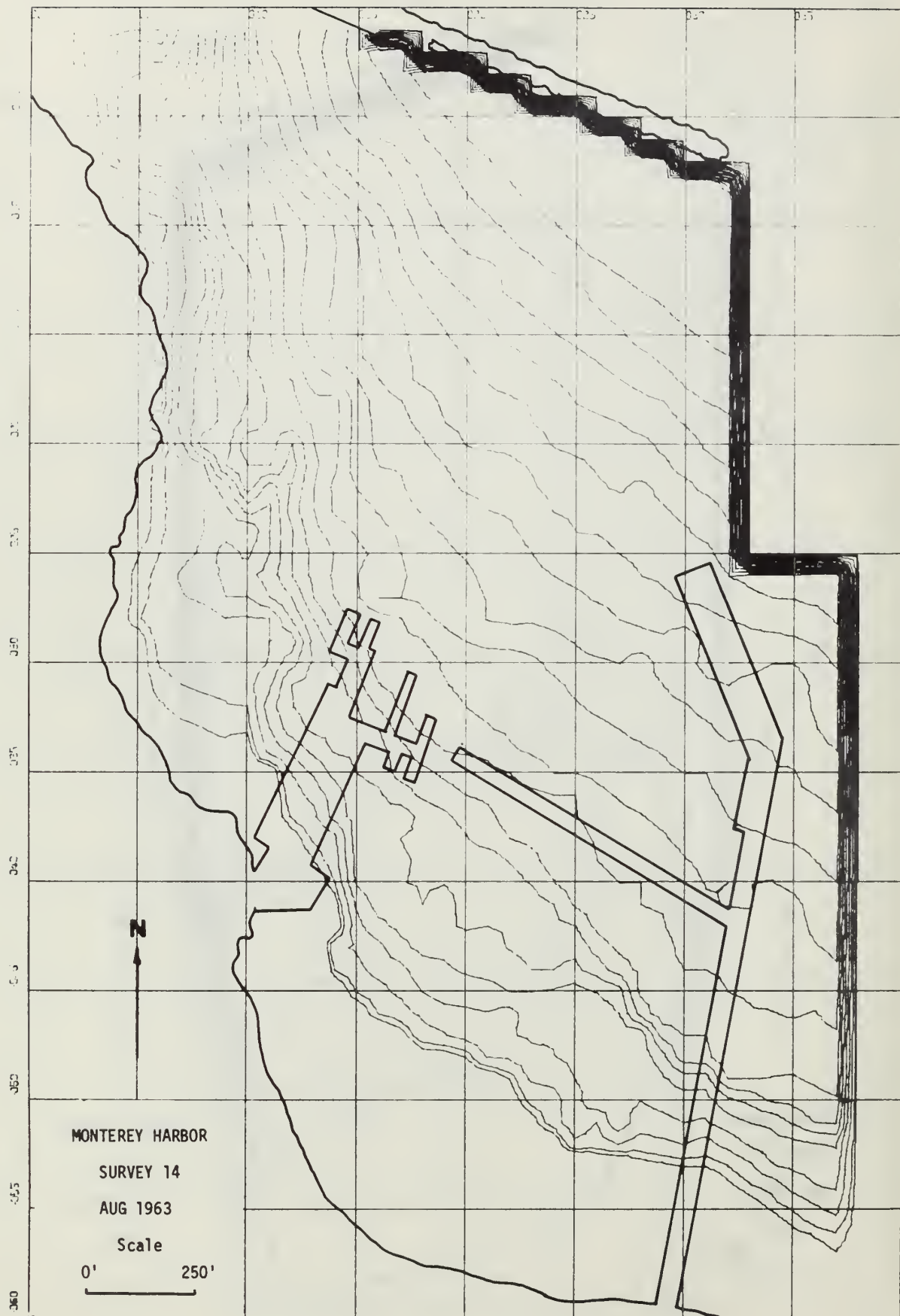




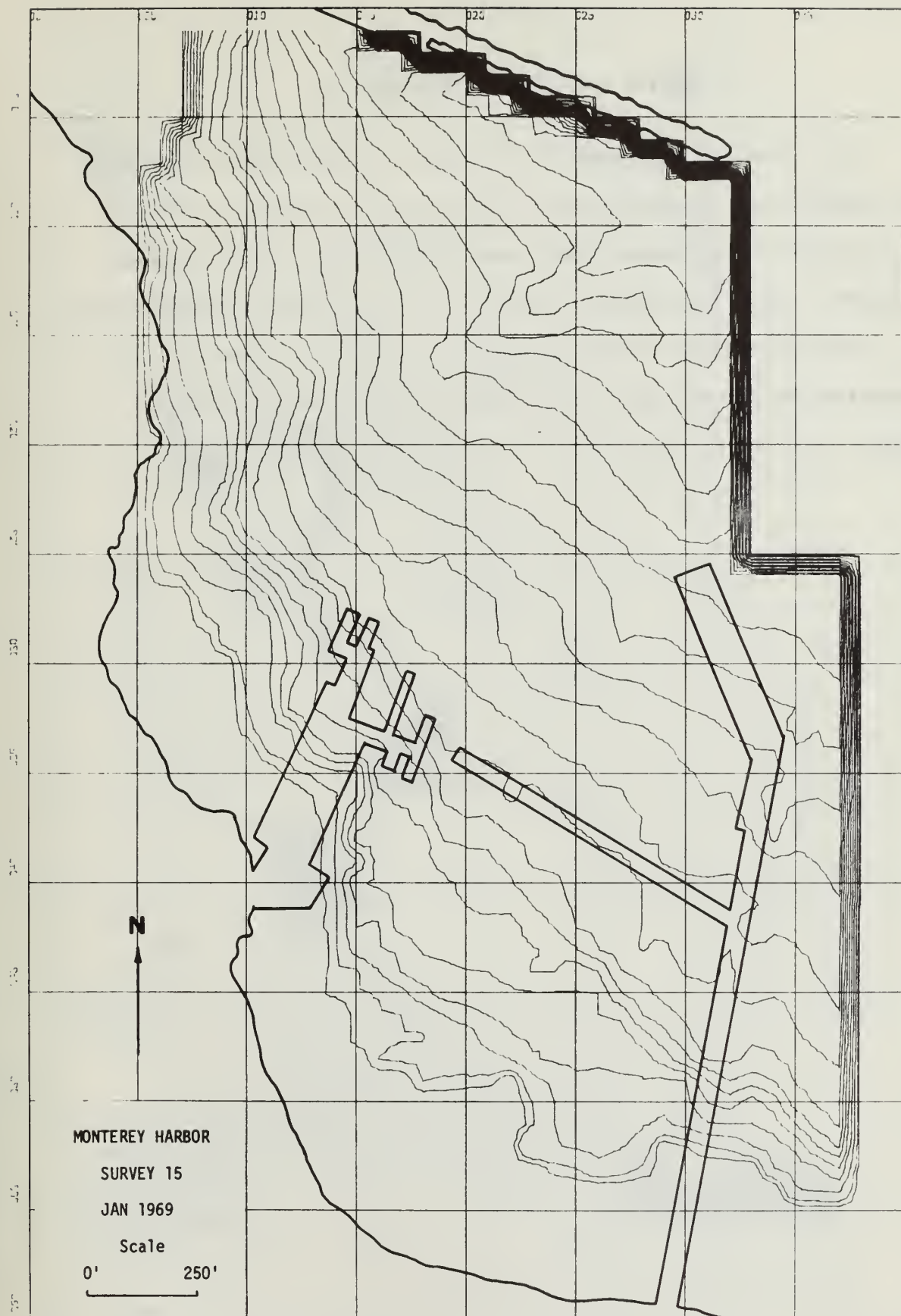












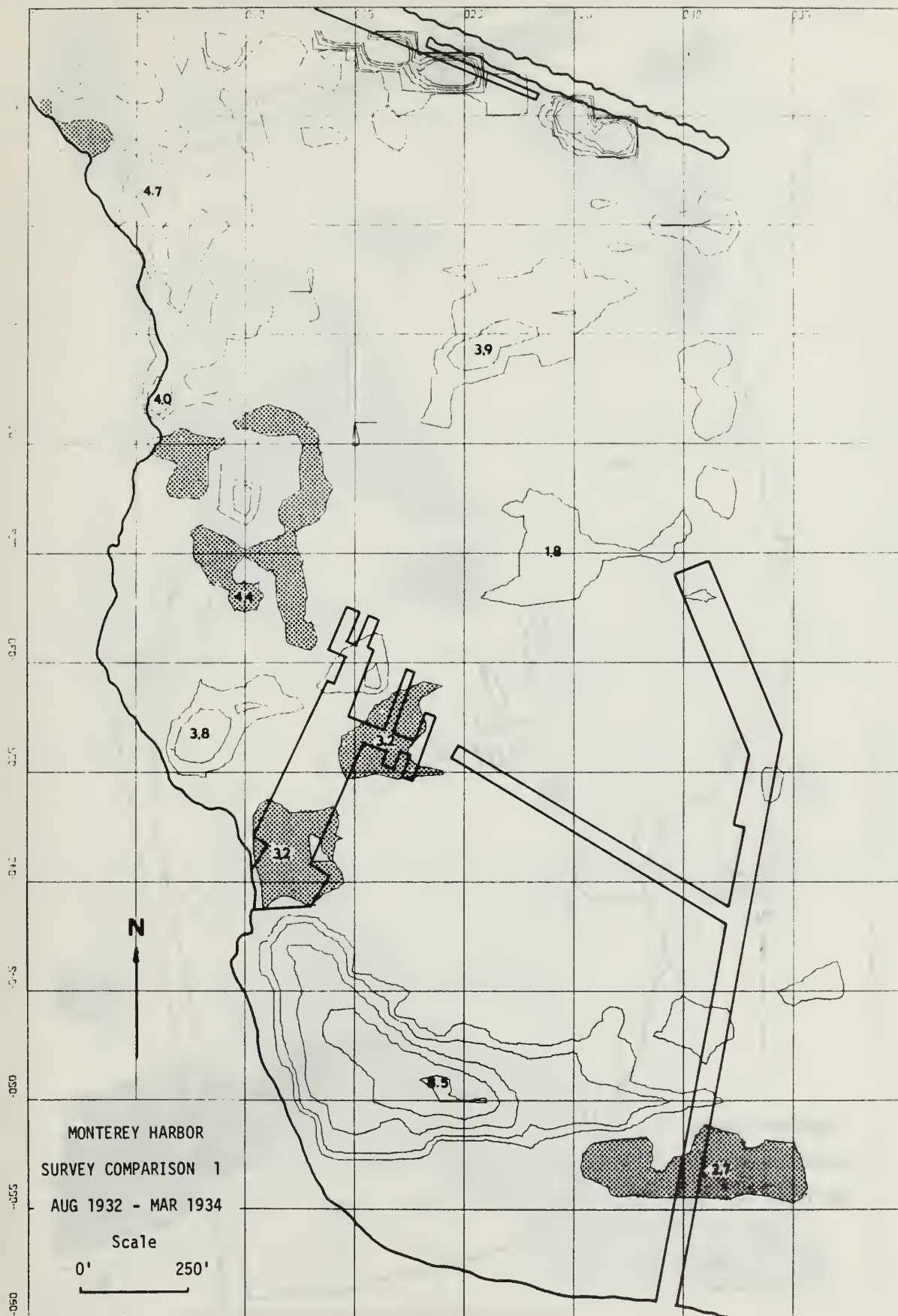


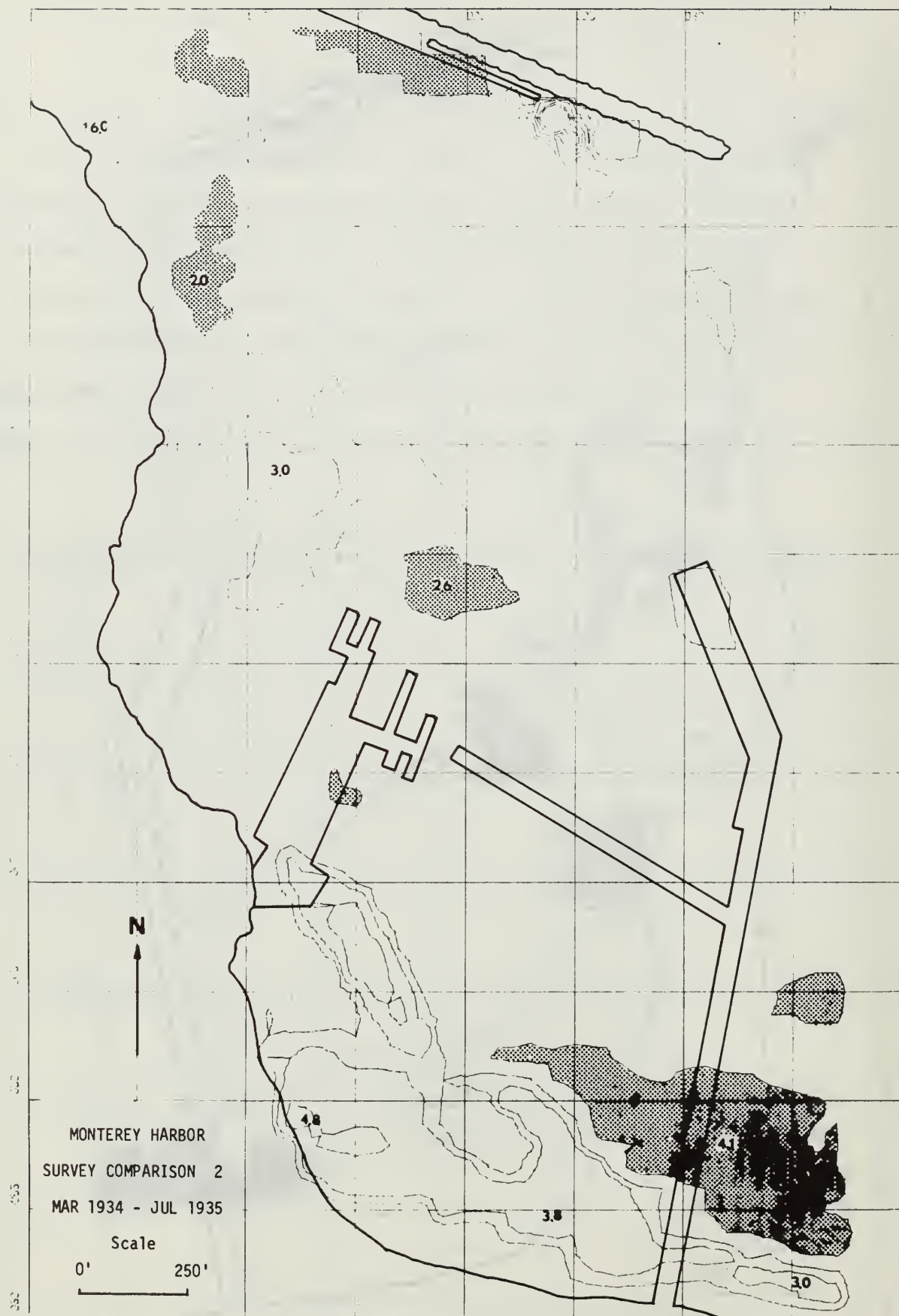
## APPENDIX B

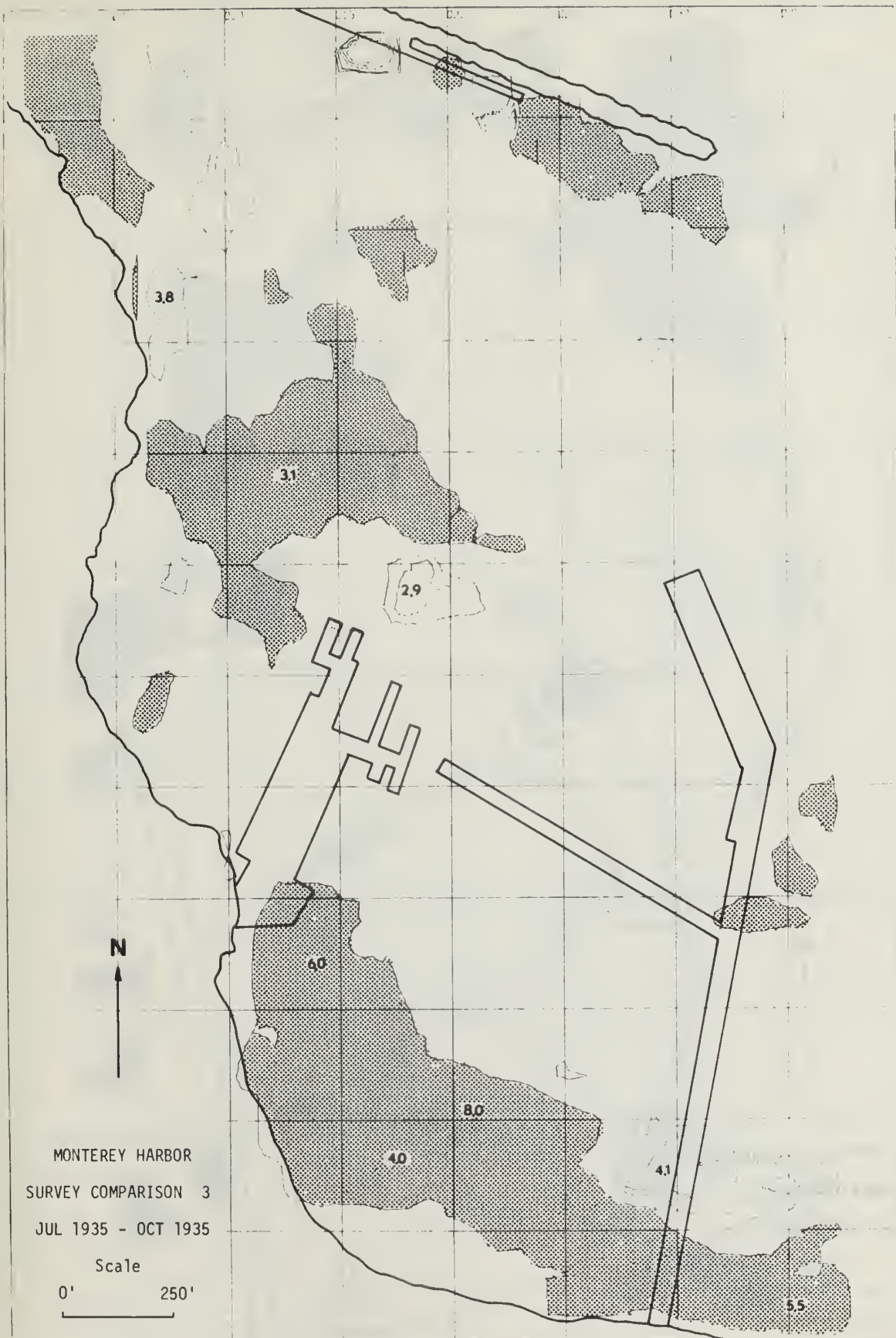
### SURVEY COMPARISONS 1 through 16

The sixteen survey comparisons listed in Table III are presented. The shaded areas indicate erosion of one foot or greater. The areas of accretion are contoured where they indicate shoaling of one foot or greater, the inner contours being 2, 4, 6, and 8 feet where required.

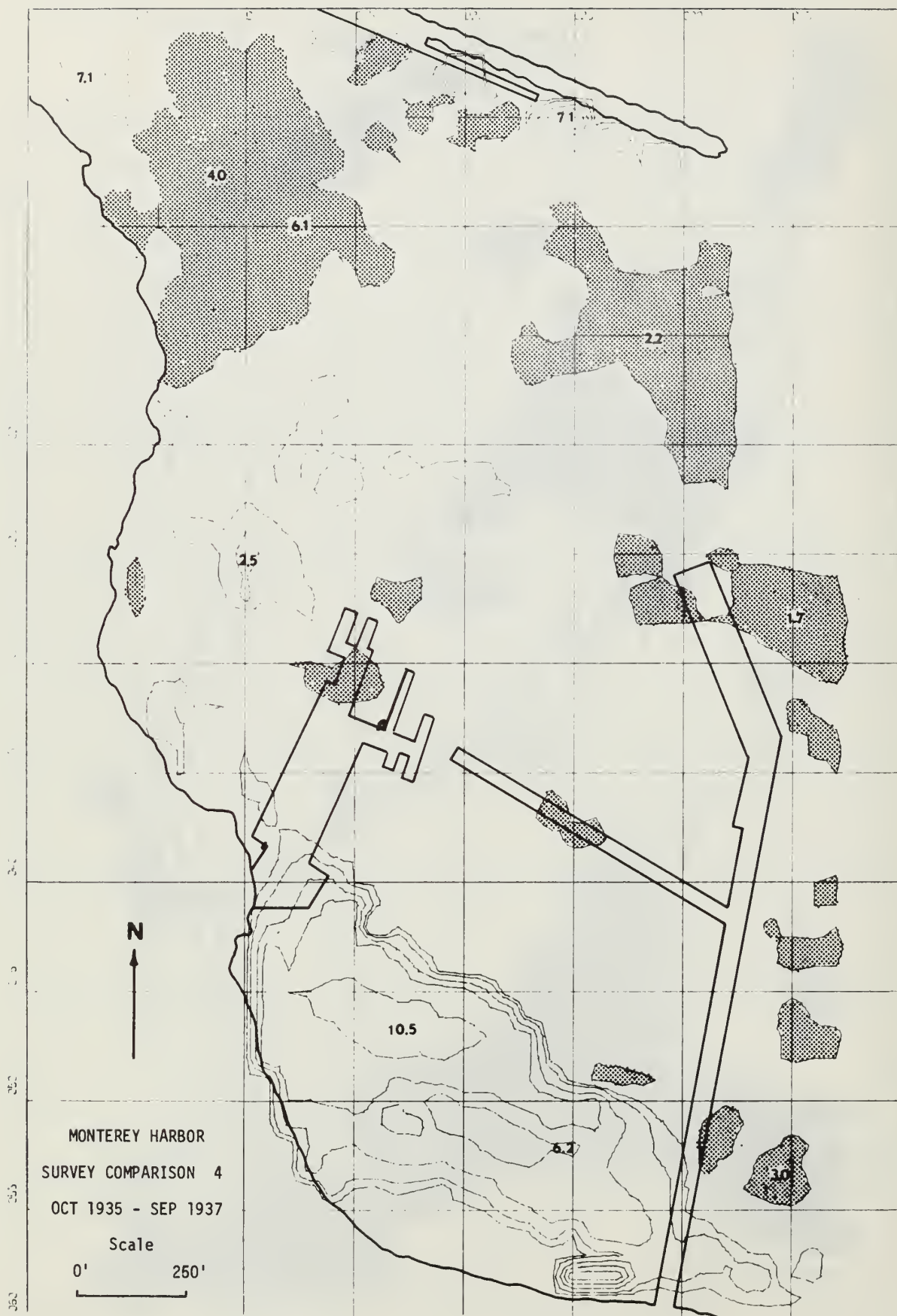
Also included are illustrations showing the area common to each comparison in relationship to the overall area delineated for the study.



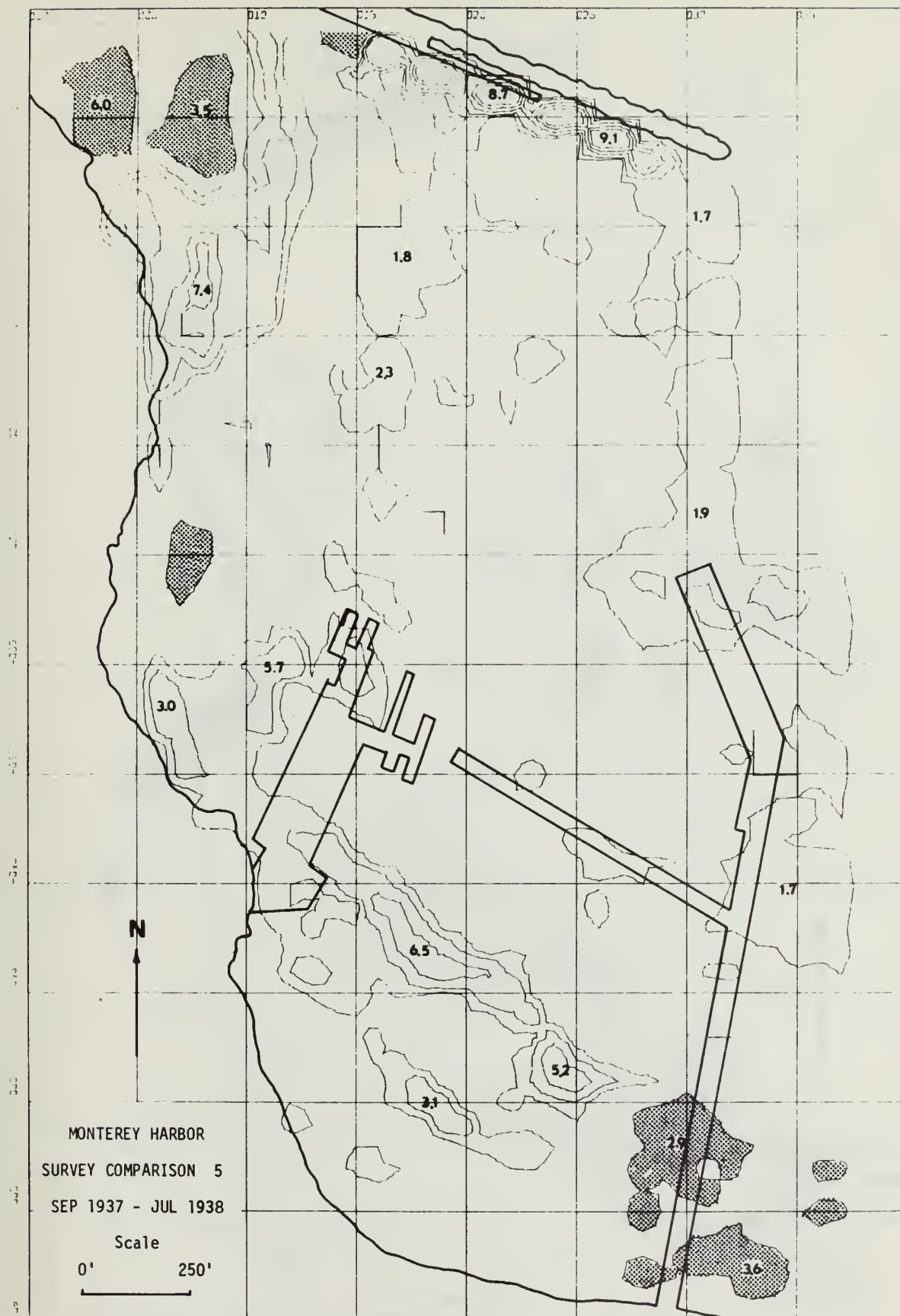


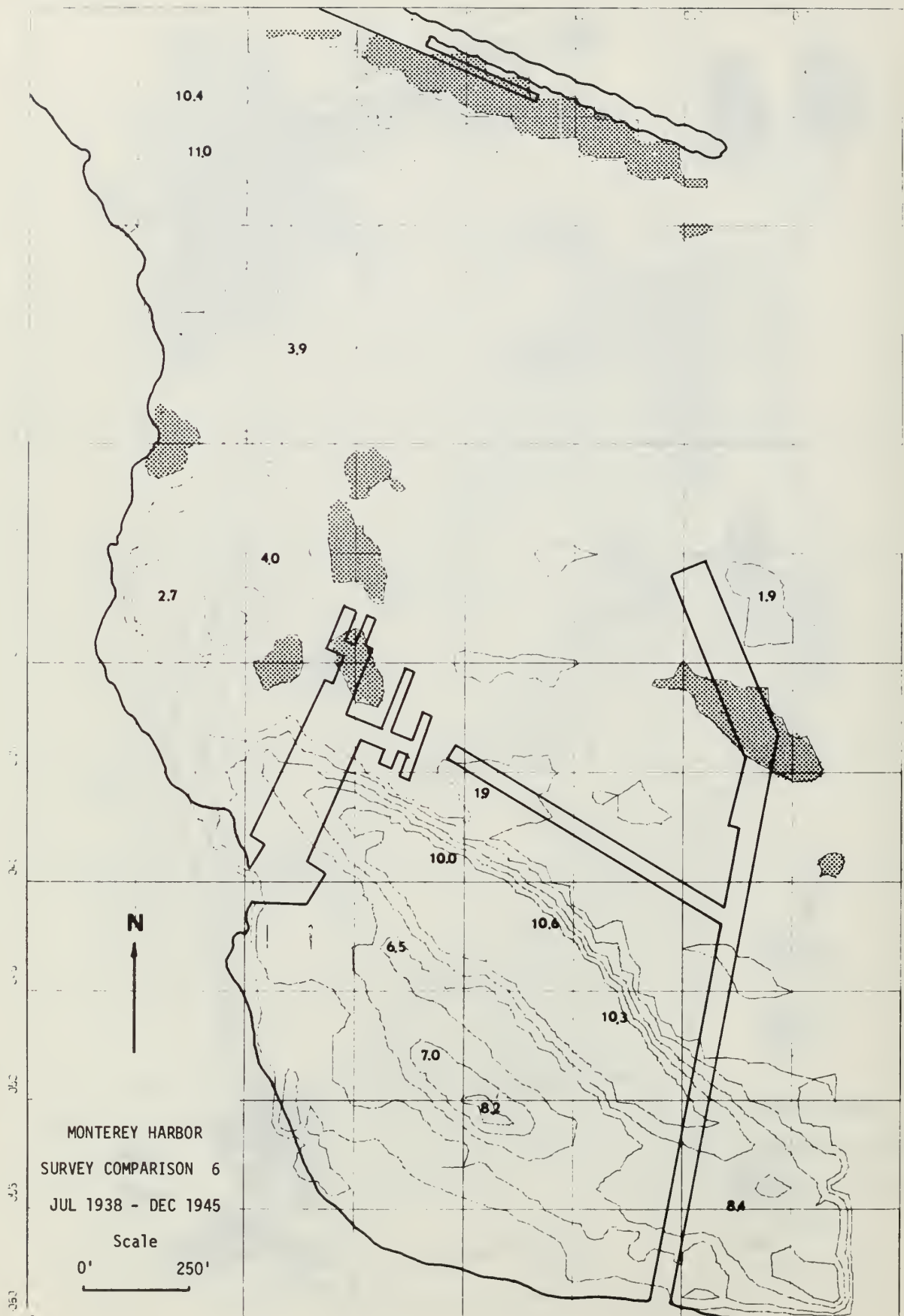


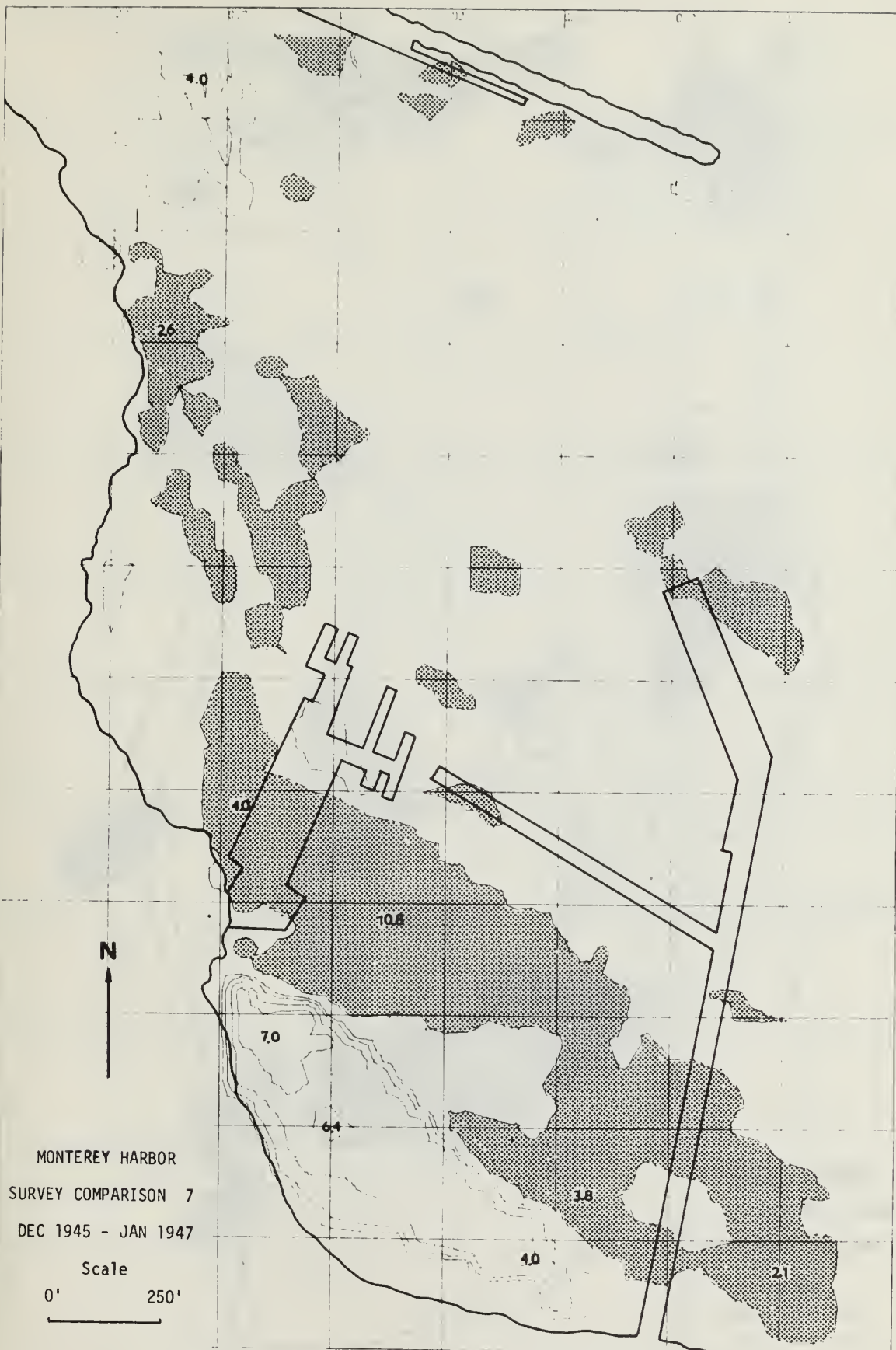




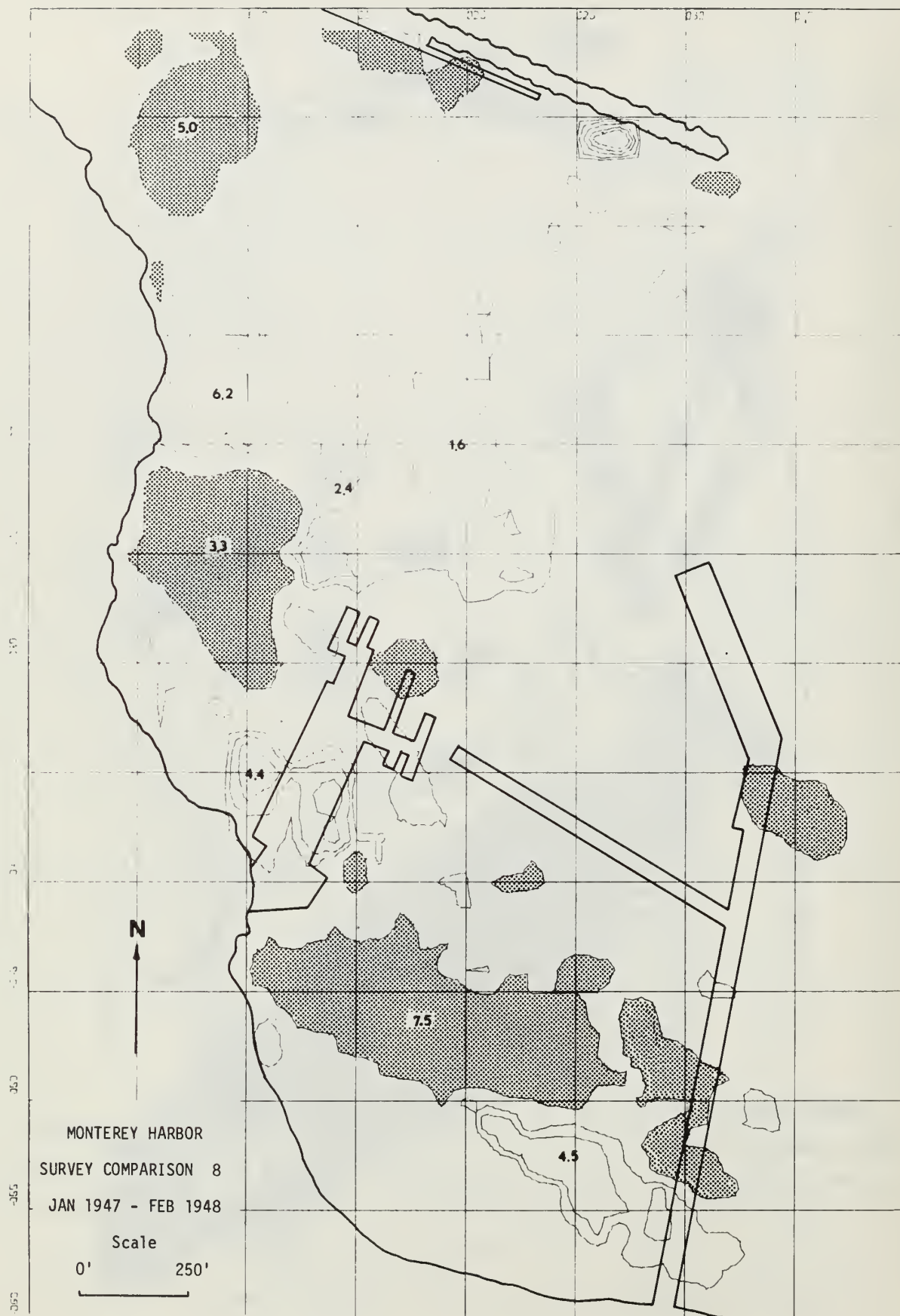


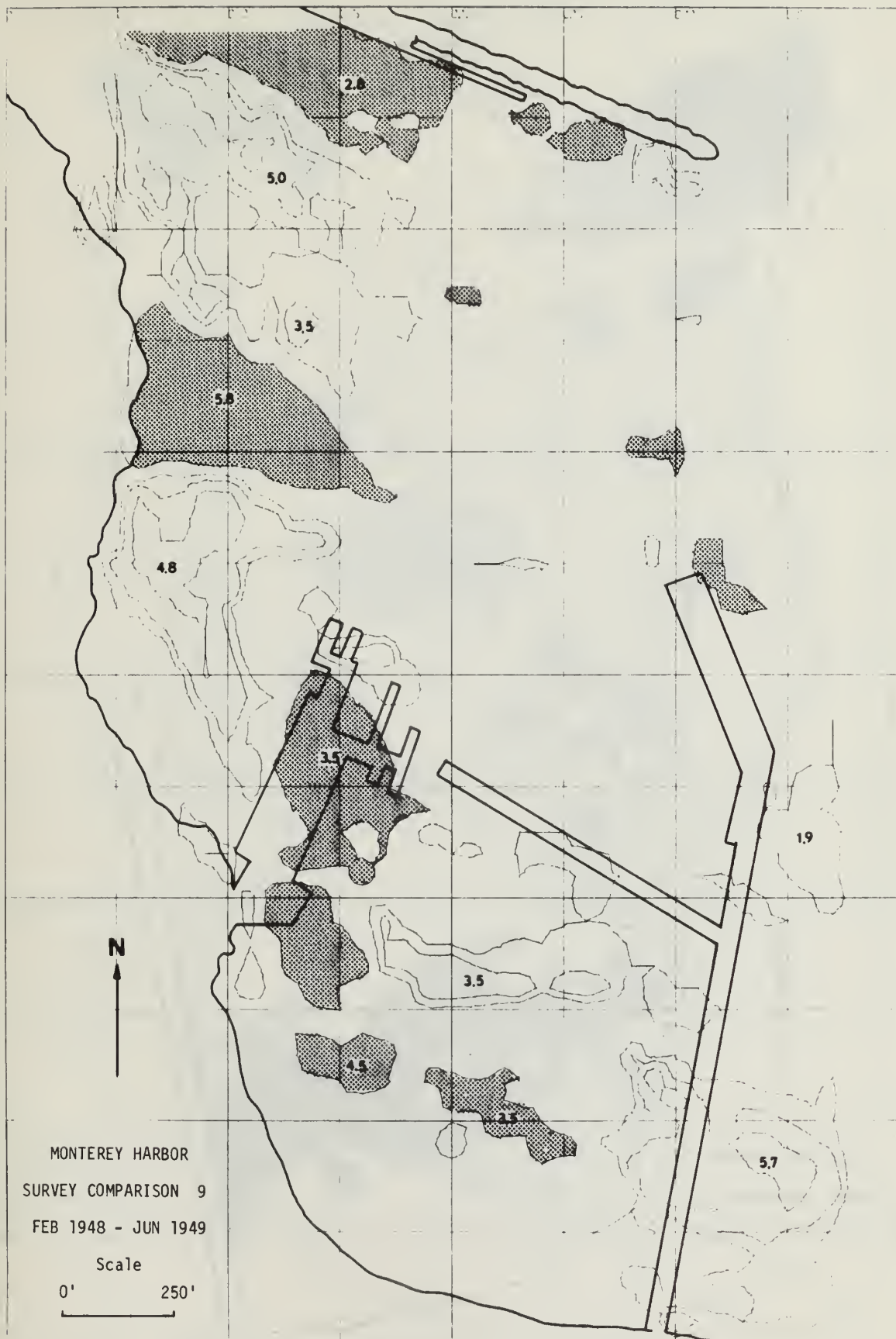




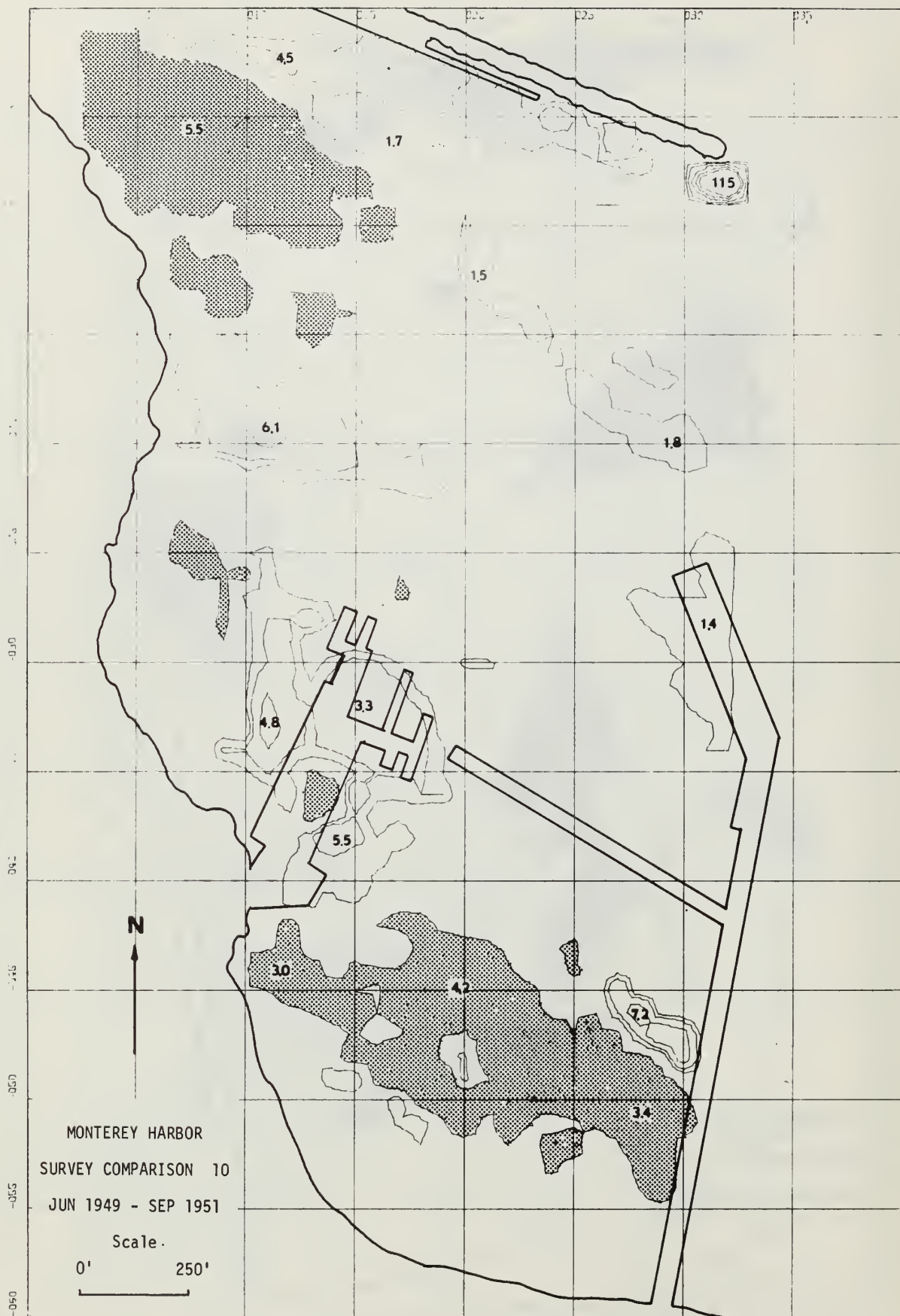


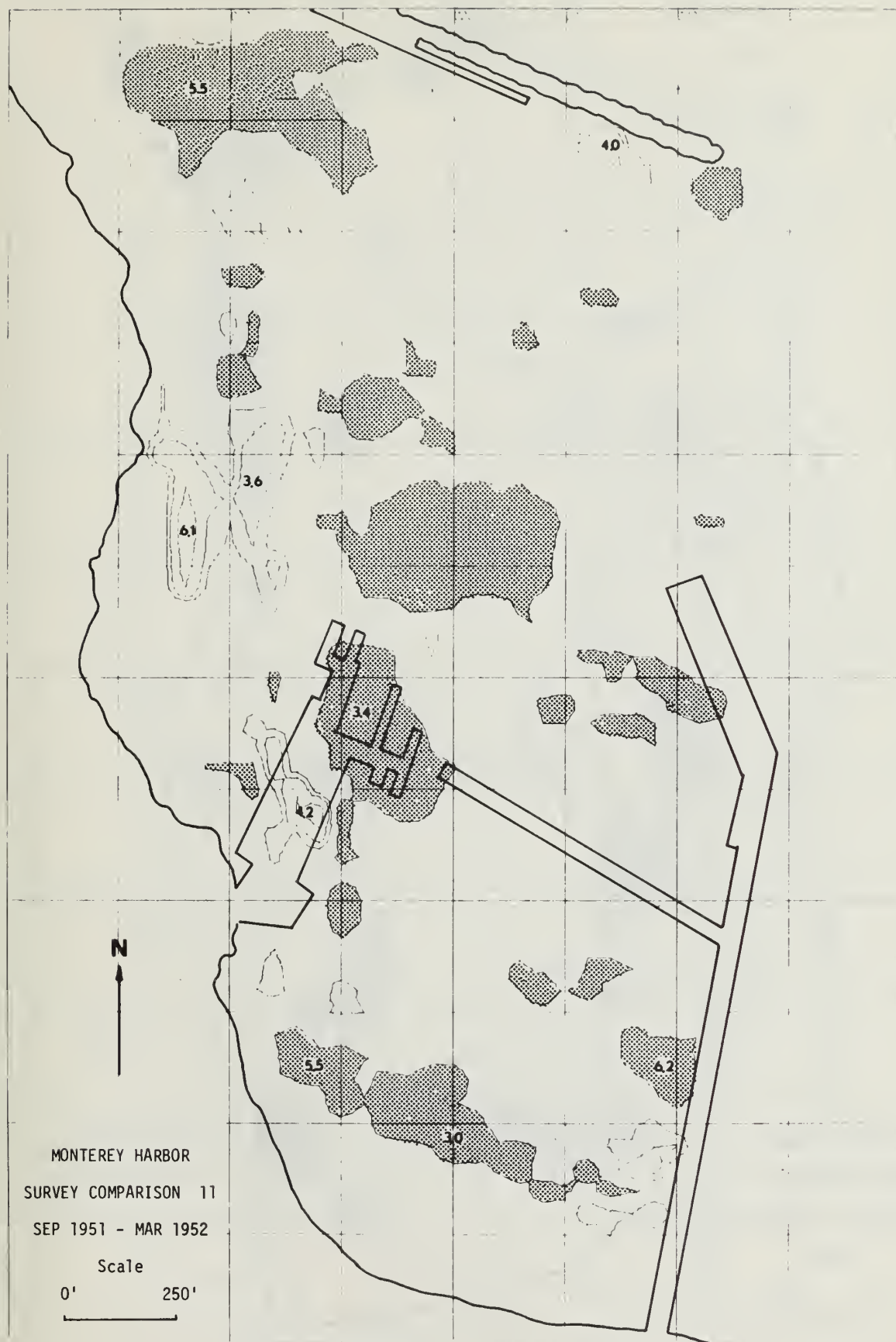


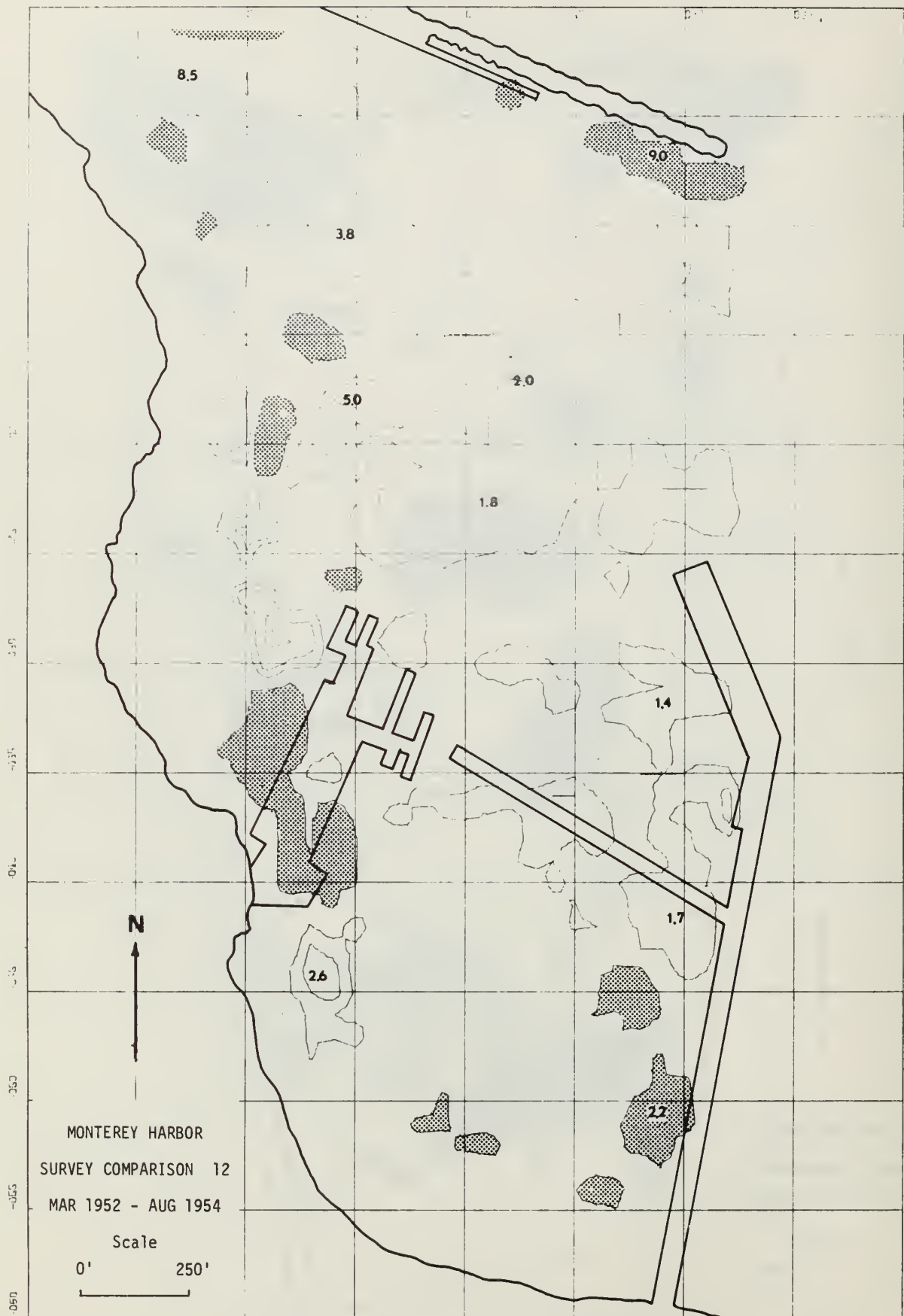


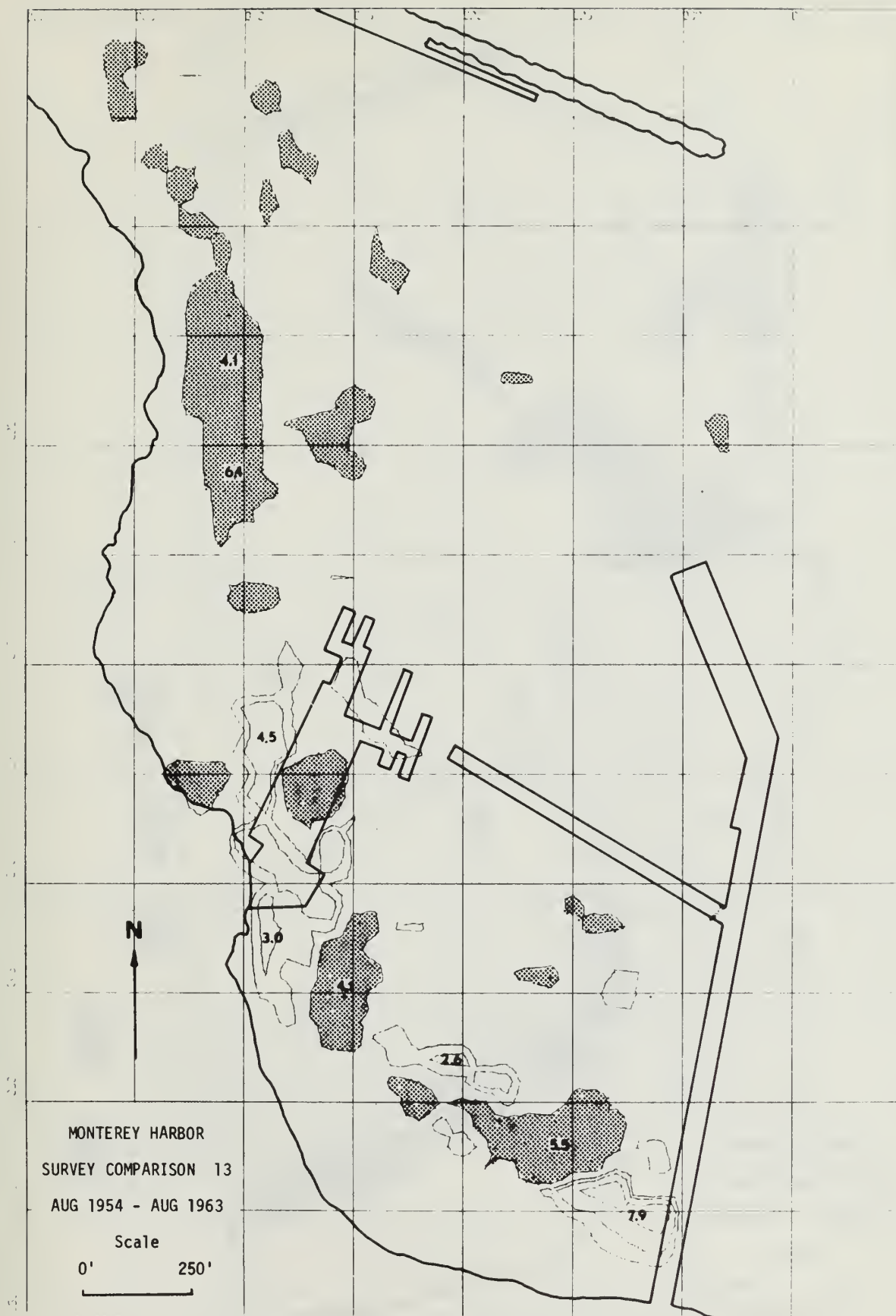




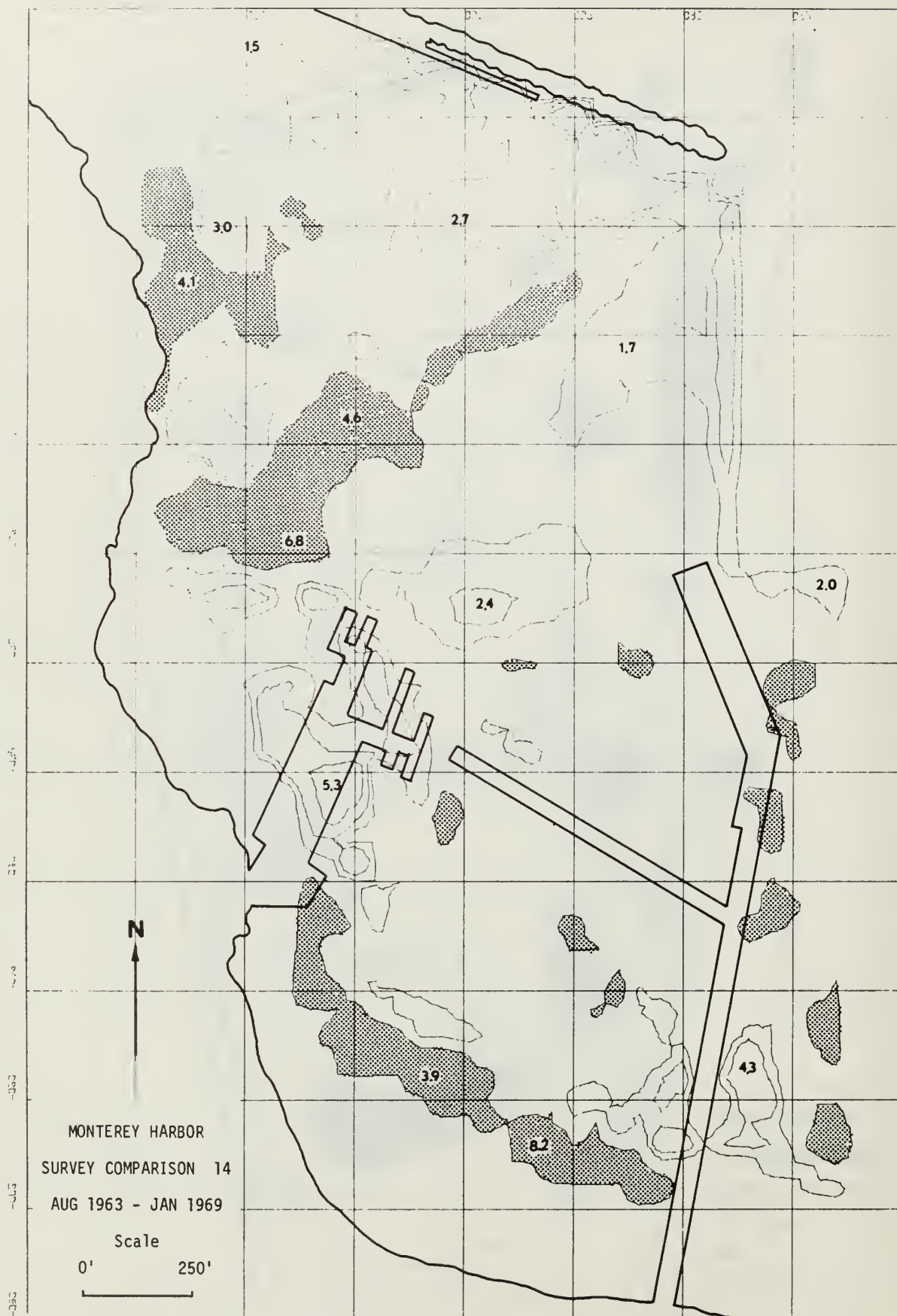




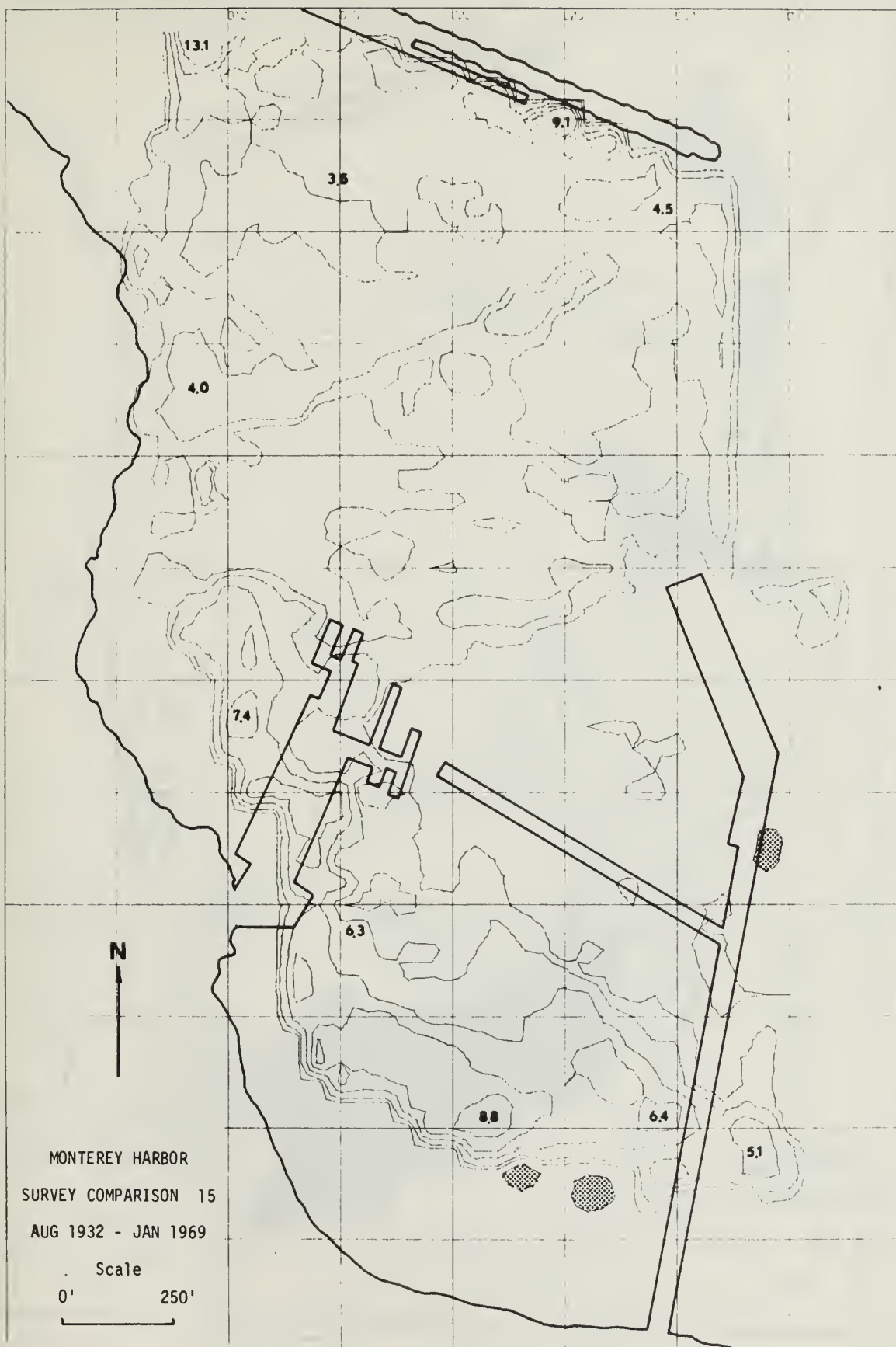


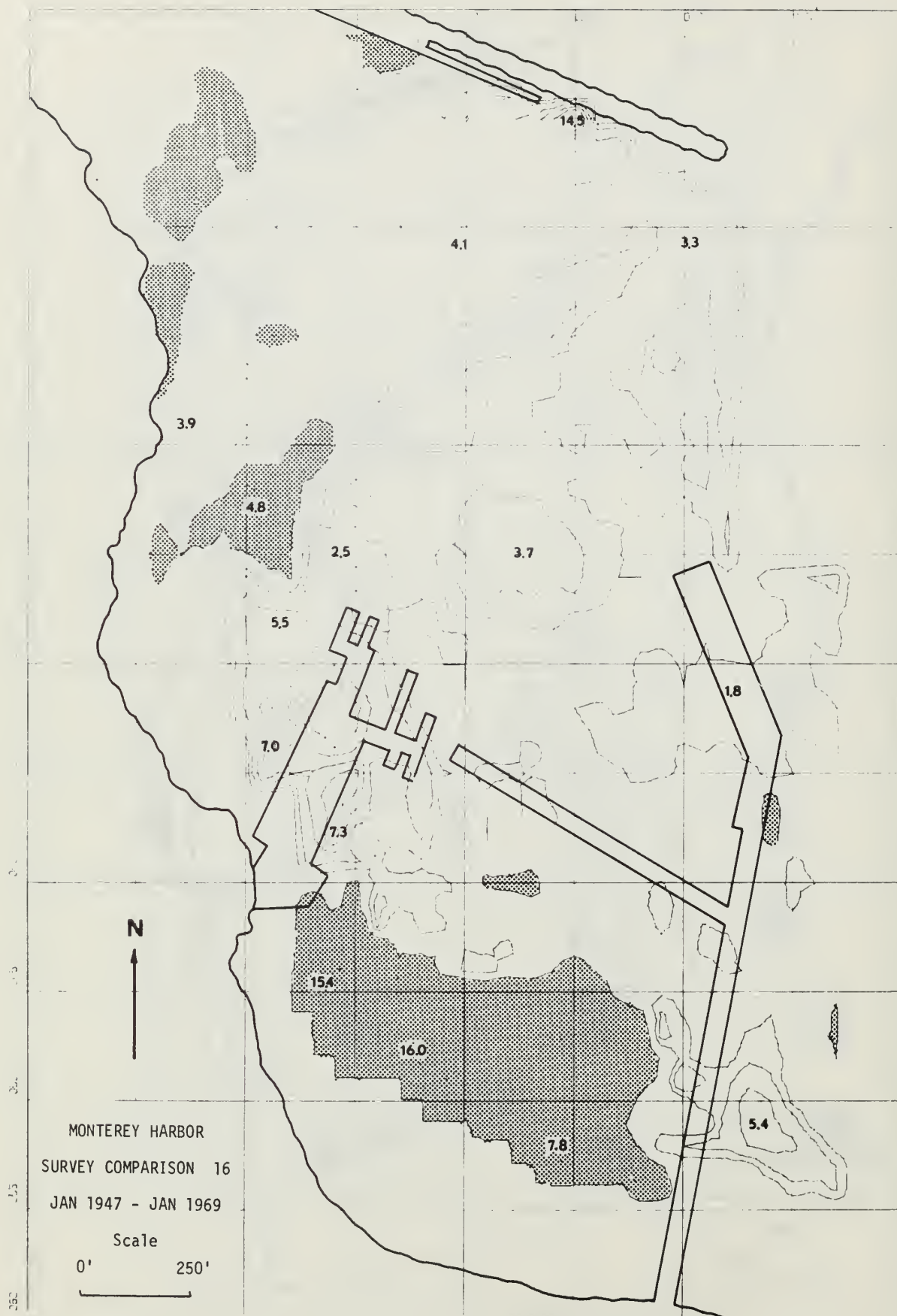


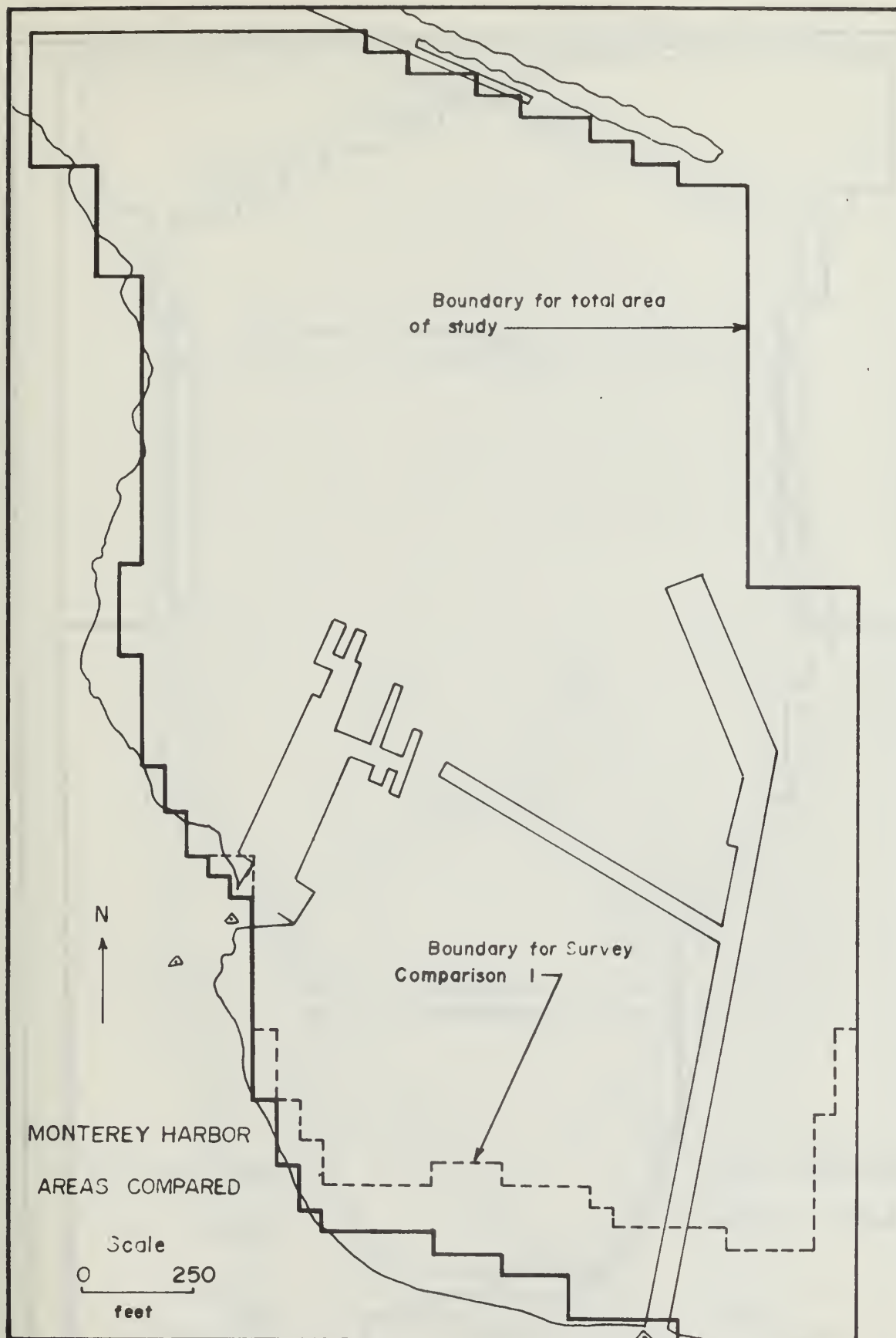


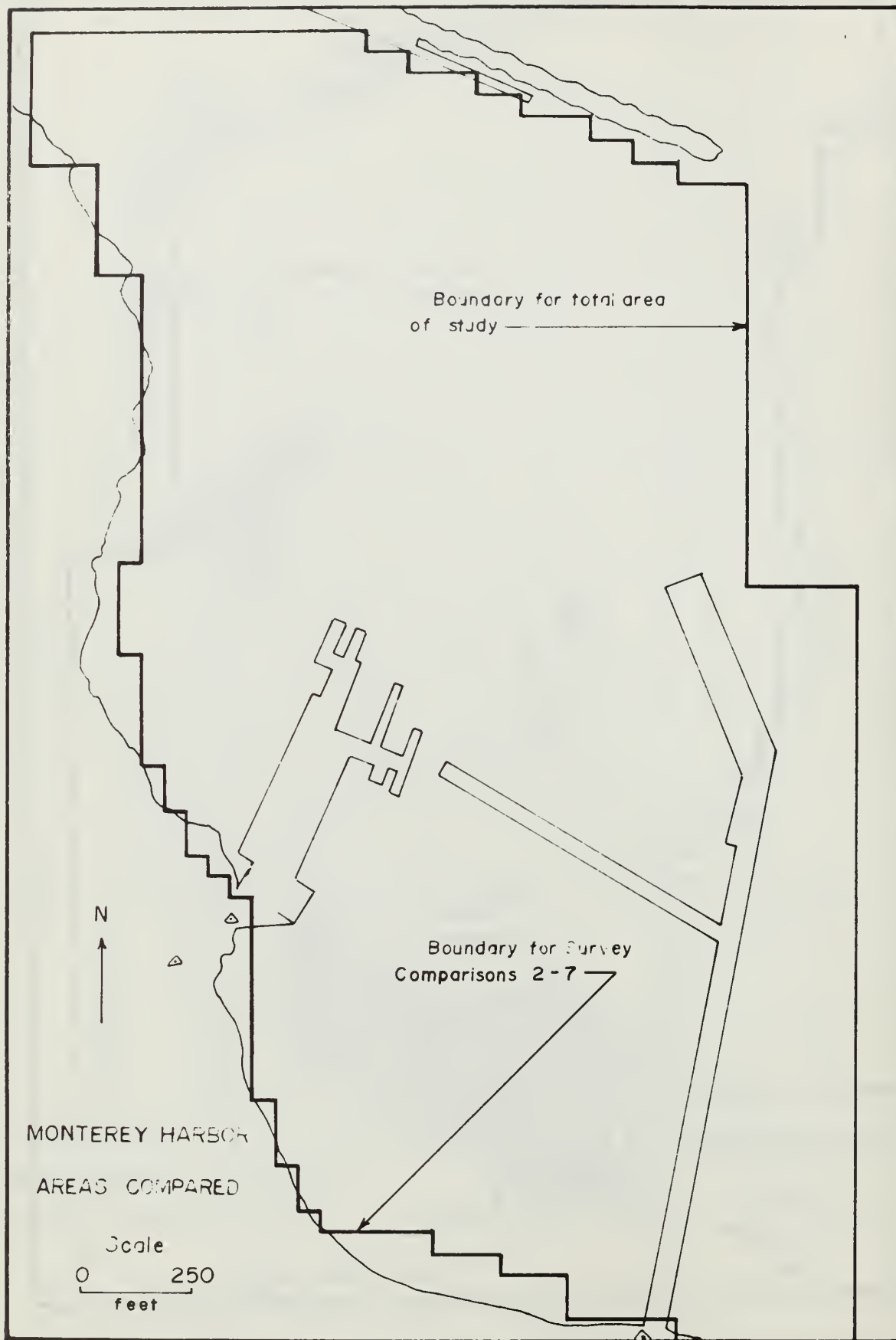




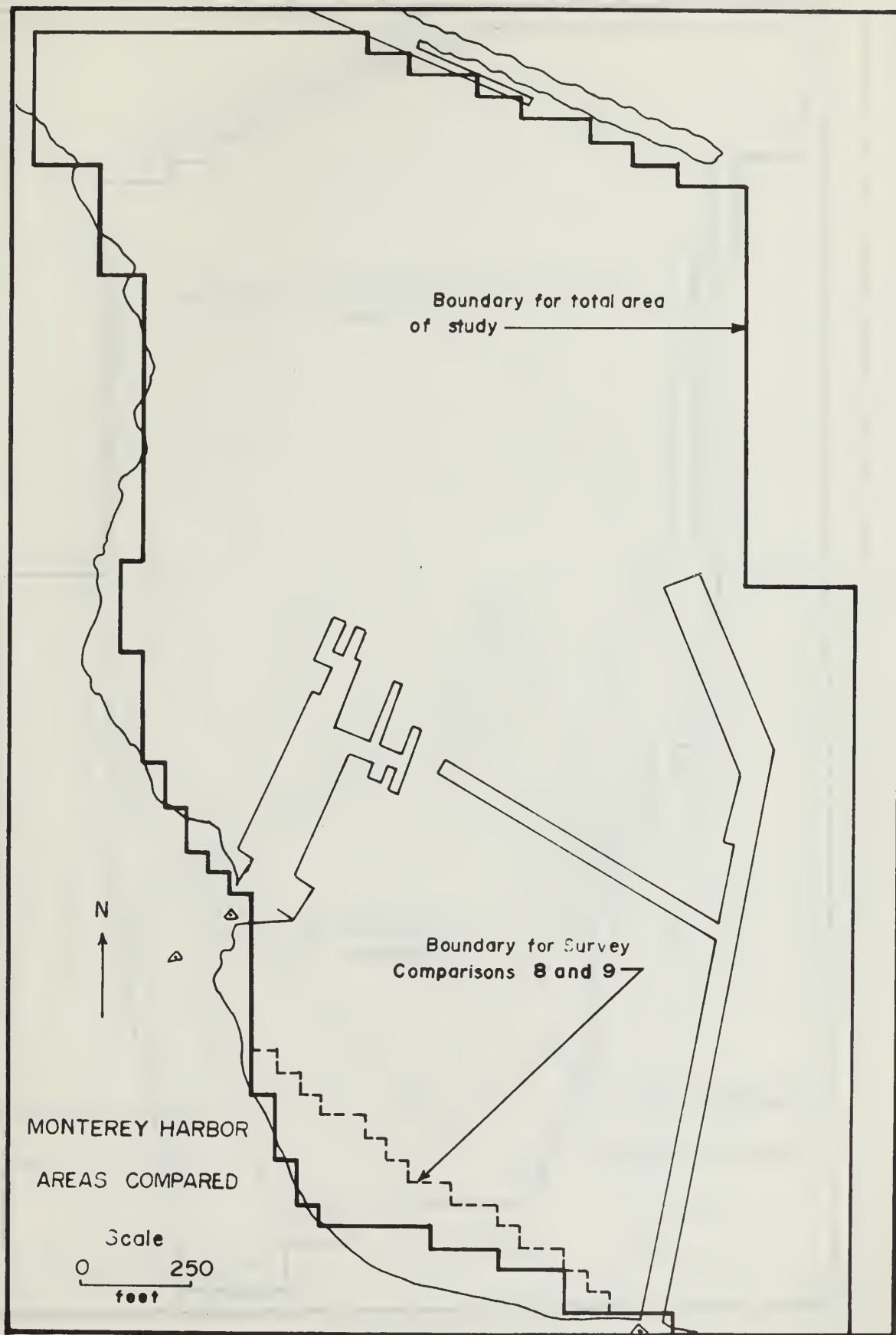


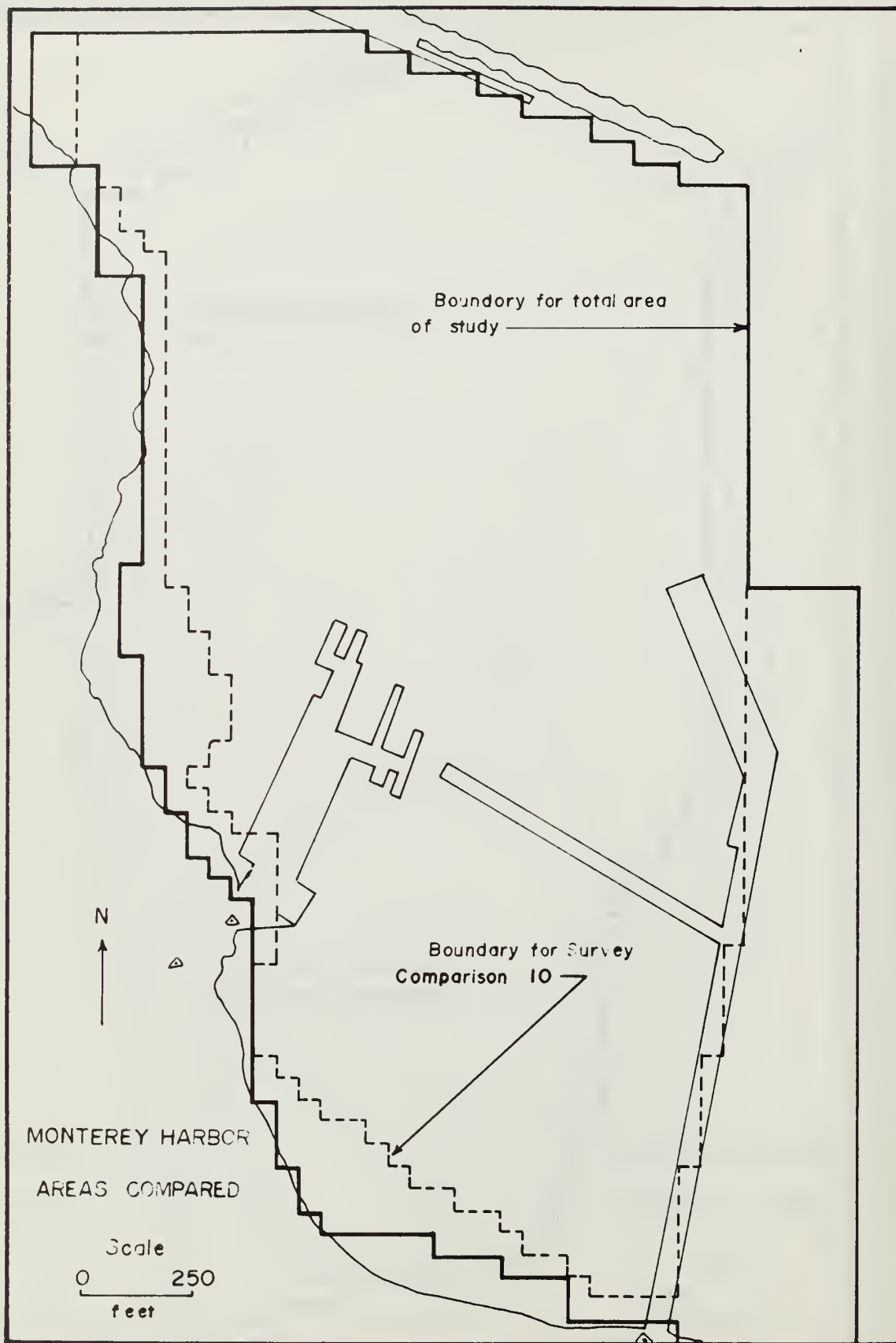


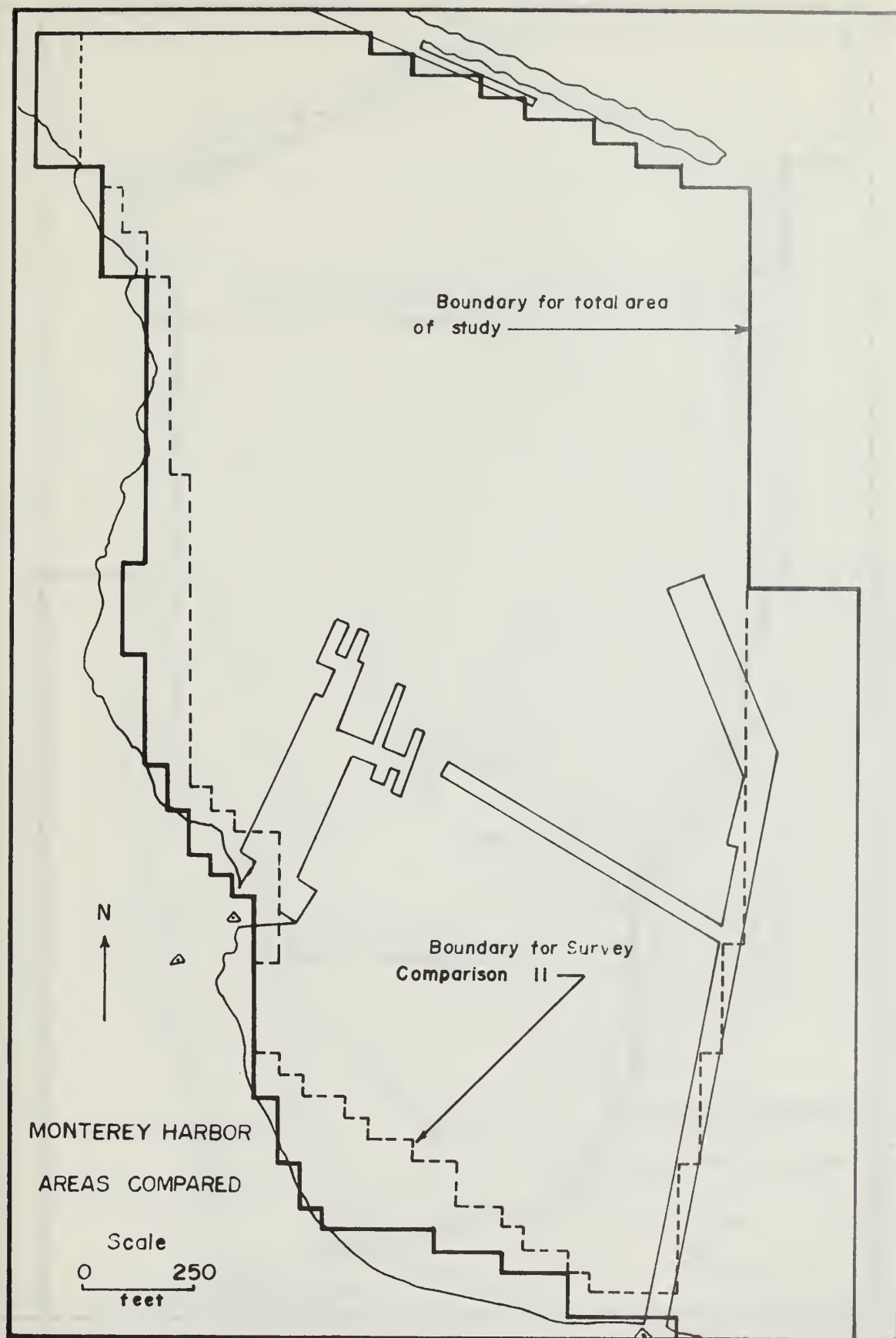


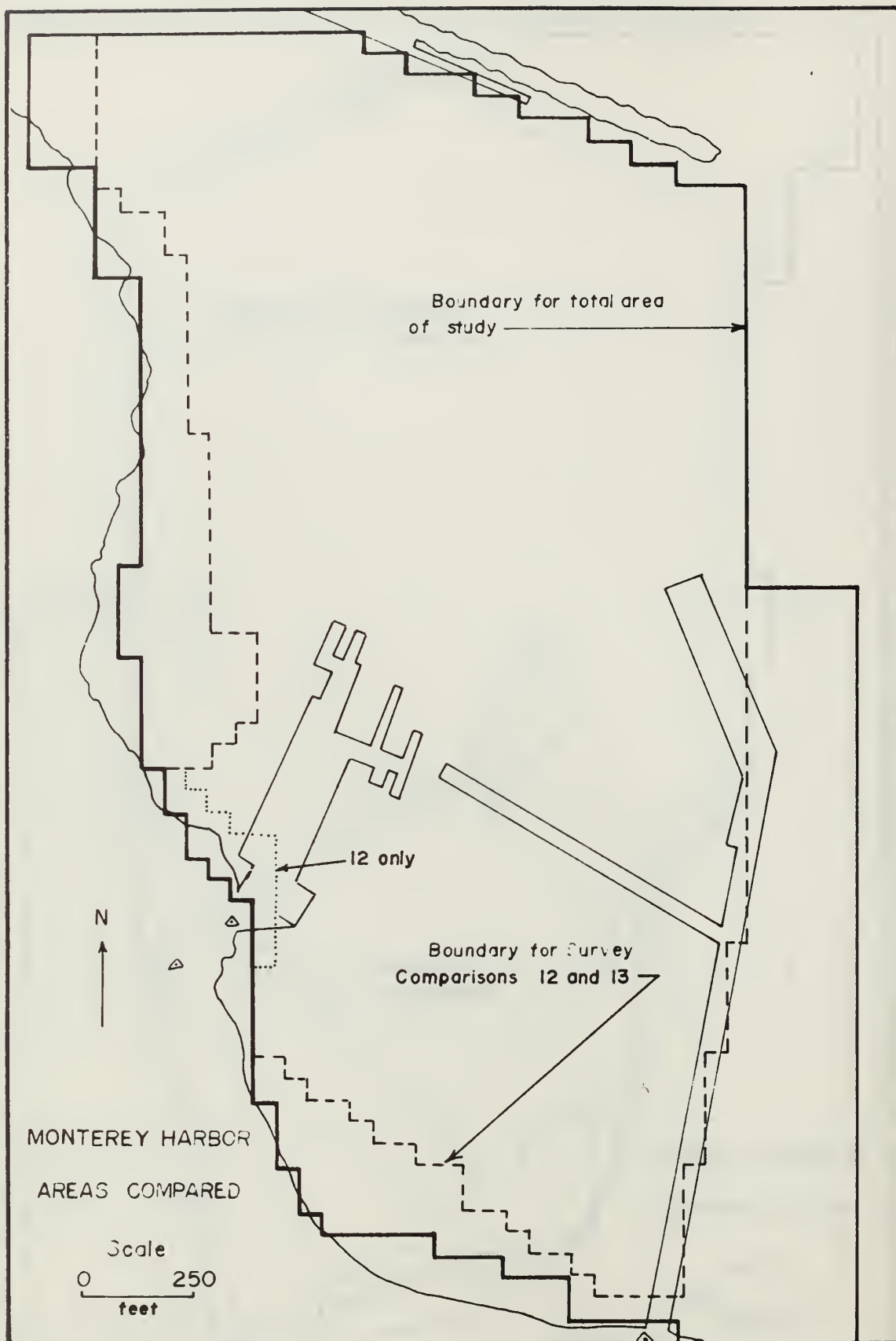


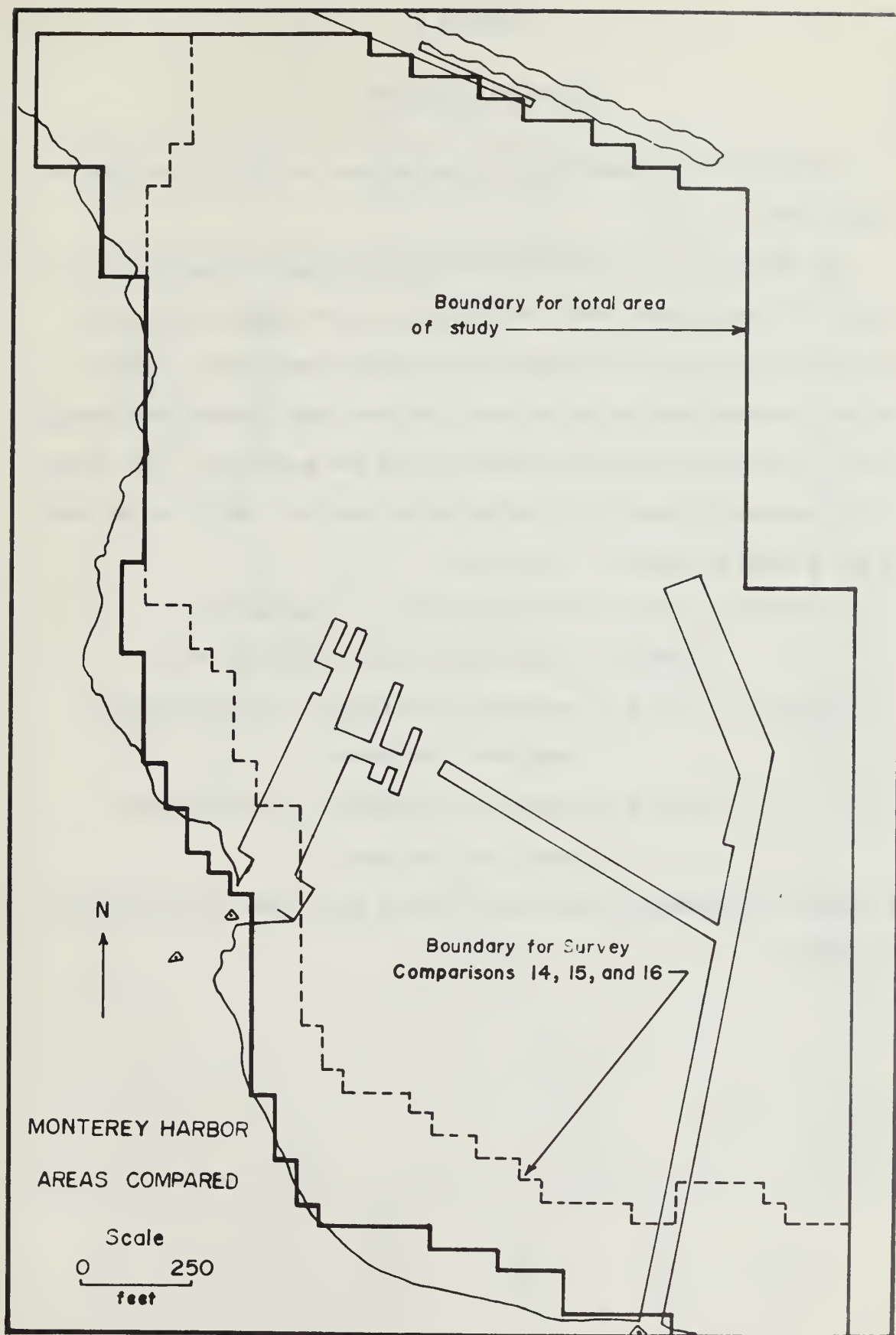














## APPENDIX C

### BOTTOM-TREND CHARTS

The bottom-trend graphs are presented here for the 44 grid points shown in Figures 8-11.

The ordinate on all graphs represents the span of years from August 1932 to January 1969. The abscissa is the depth relative to Mean Lower Low Water. The depth scale differs from graph to graph, and has been designed so as to cover just the range between the maximum and minimum values of depth observed at any one grid point. The scales are in computer exponential floating-point notation, which can be read as the following examples illustrate:

Ordinate: 3.262 E 01 represents 32.62, or August 1932

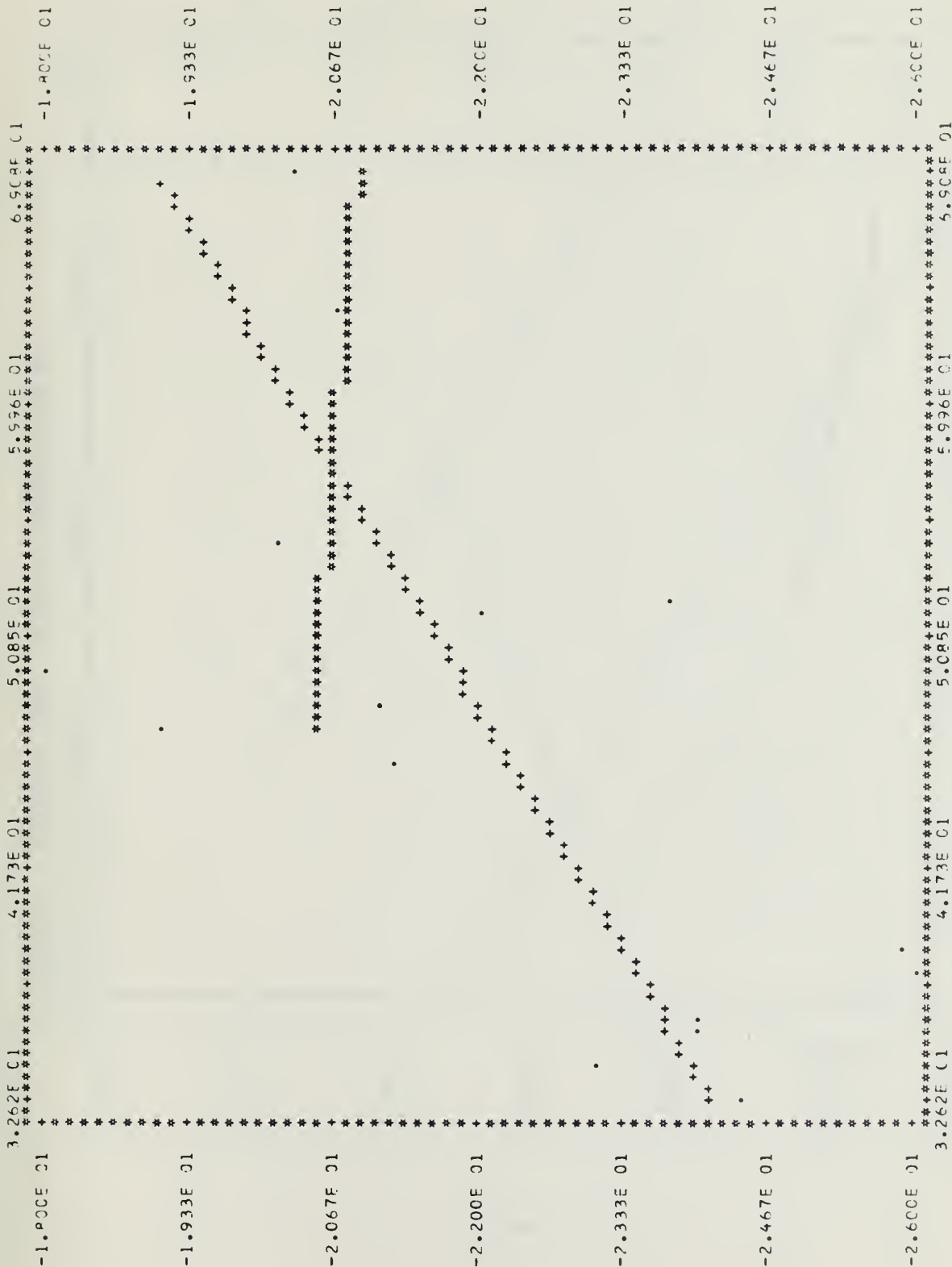
6.908 E 01 represents 69.08, or January 1969

Abscissa: 3.333 E 00 represents a height of 3.333 feet above  
Mean Lower Low Water

-2.200 E 01 represents a depth of 22.00 feet below  
Mean Lower Low Water

The trends and standard deviations in depth are listed at the bottom of each graph.

GRIP PCINT 1



## GRID POINT

2

3.262E 01

4.173E 01

5.085E 01

5.9965 01

6.9045 9

-1.450E C1

-1.450F 01

-1.575E 01

-1.575E 01

-1.700E 01

-1.700E 01

-1.825E 01

-1.825E 01

-1.950E 01

-1.950E 01

-2.075E 01

-2.075E 01

-2.200E 01

-2.200E 01

3.262E 01

4.173E 01

5.085E 01

5.996E 01

6.908E 01

1932-1969  
1947-1969

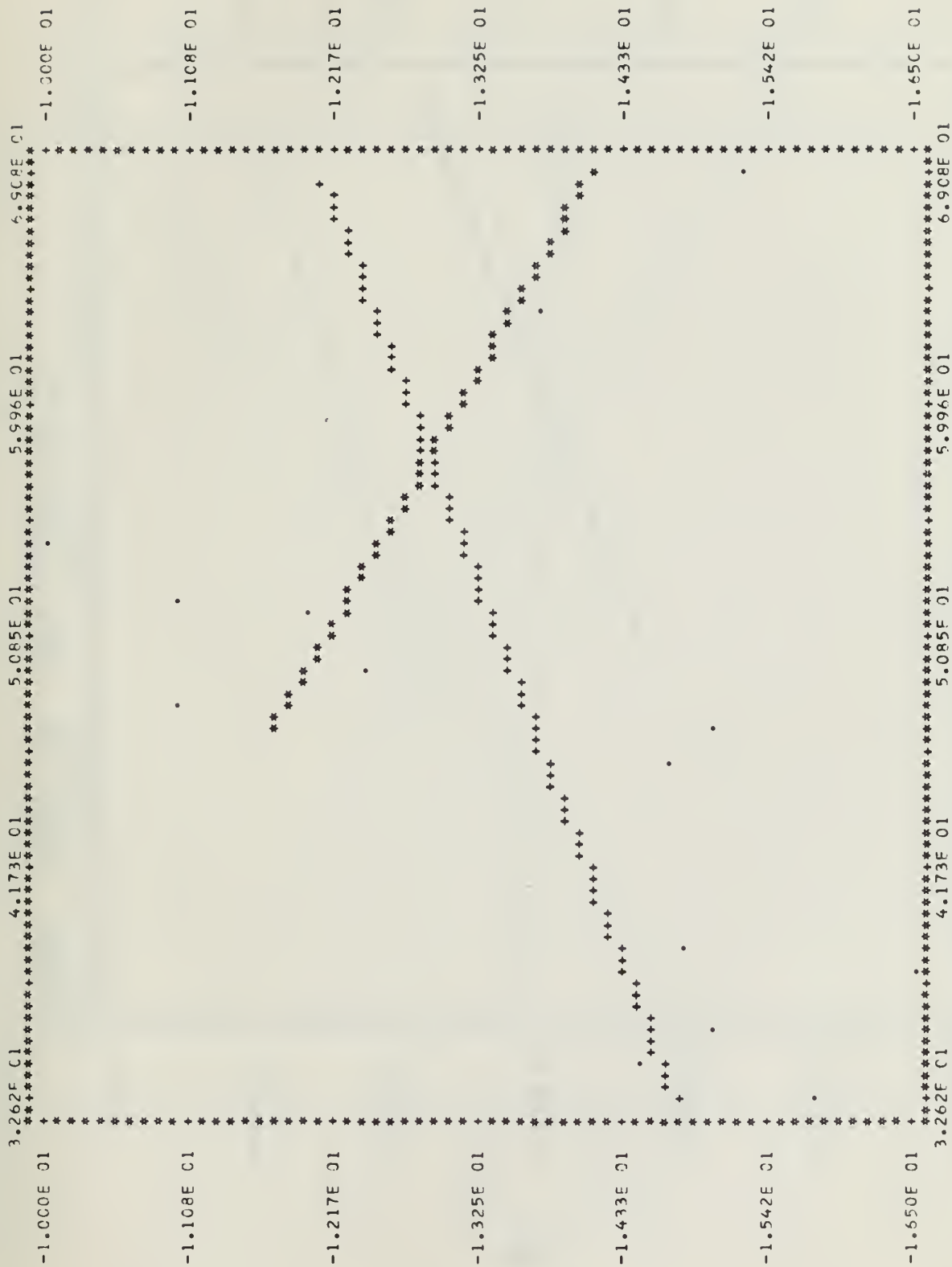
1932-1969  
1947-1969

STD	DEV	1.31
STD	DEV	0.53

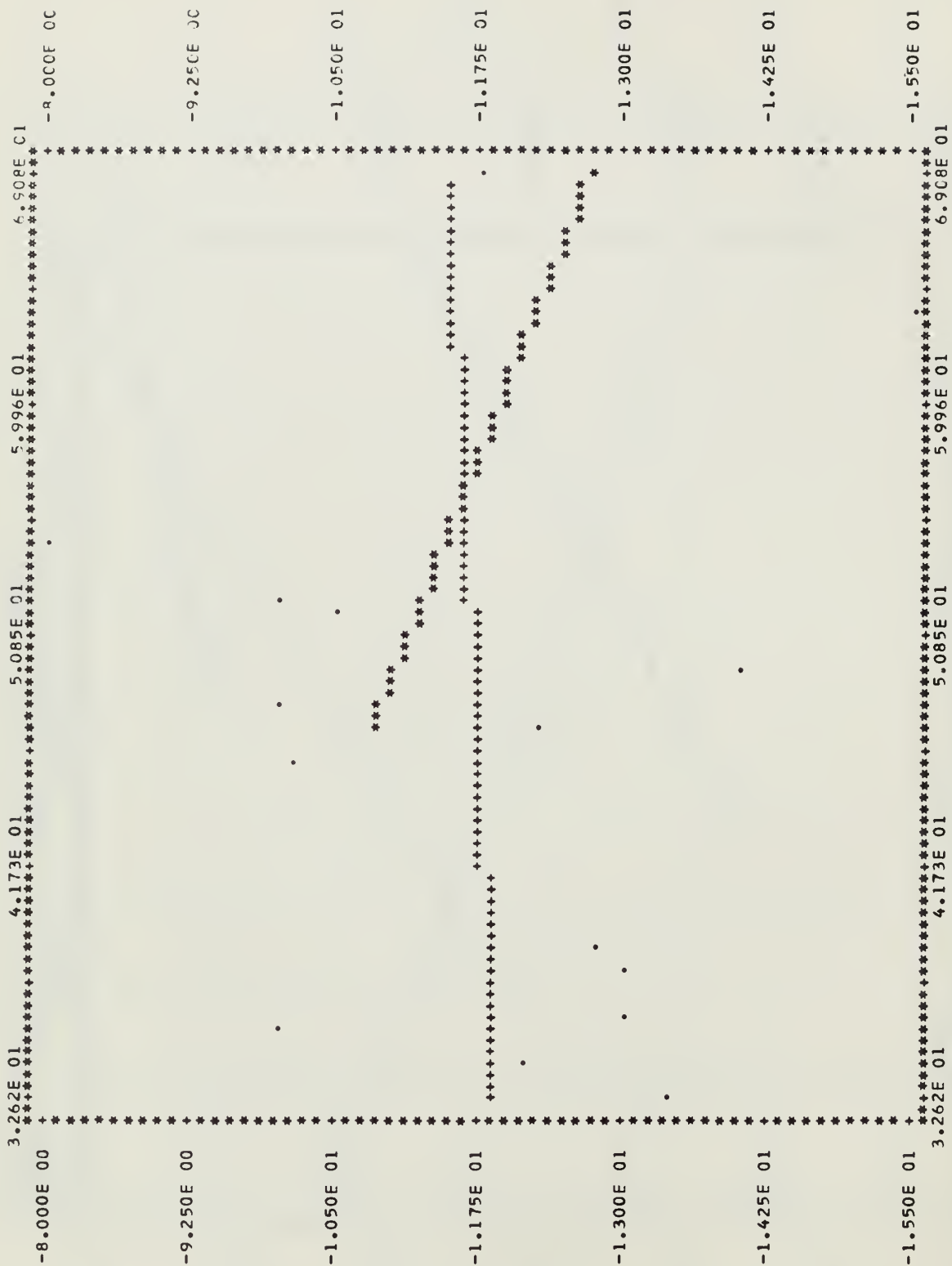
STD	DEV	1.31
STD	DEV	0.53

TREND  
TREND  
TRENDTREND  
TREND  
TREND

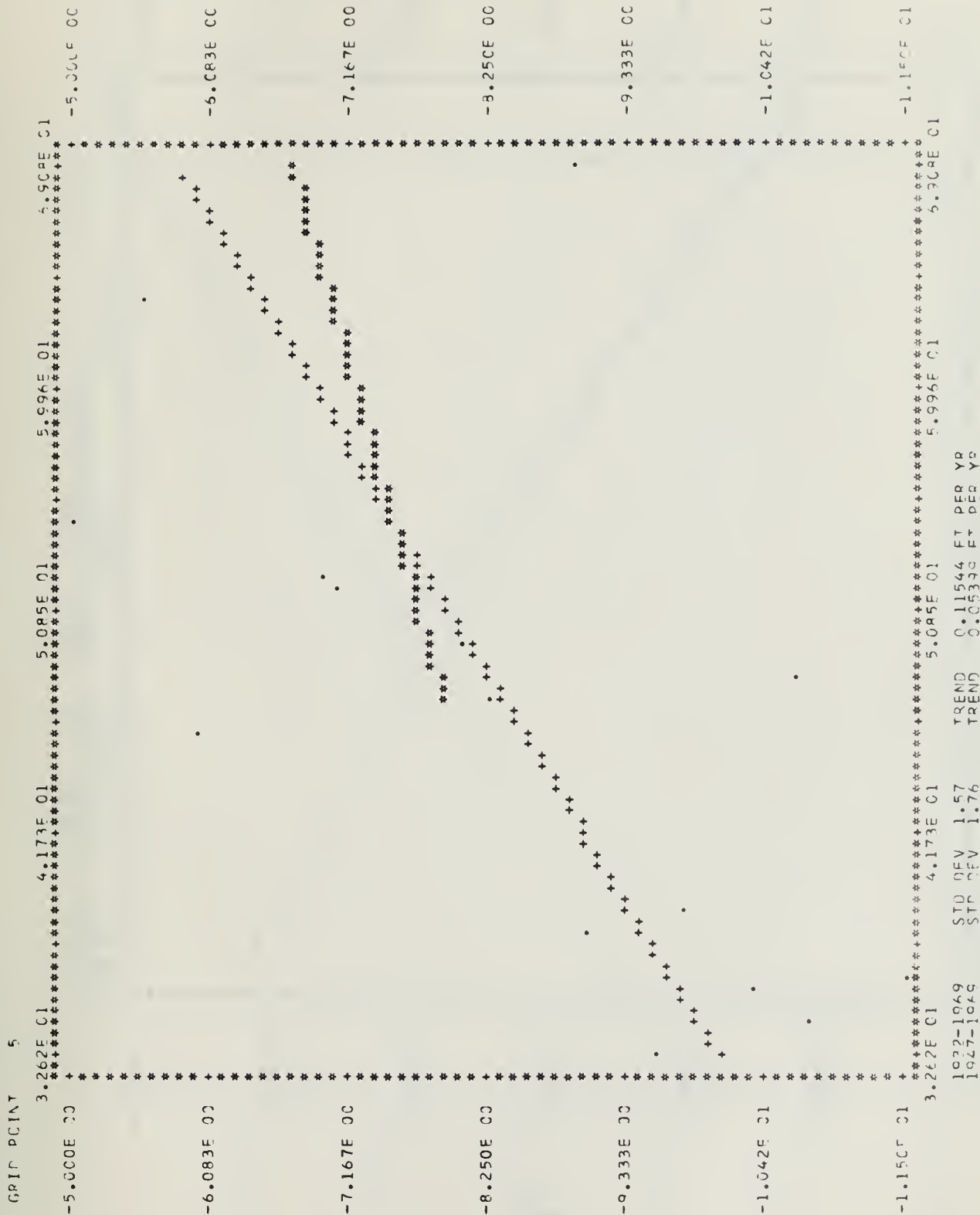
GRID POINT 3



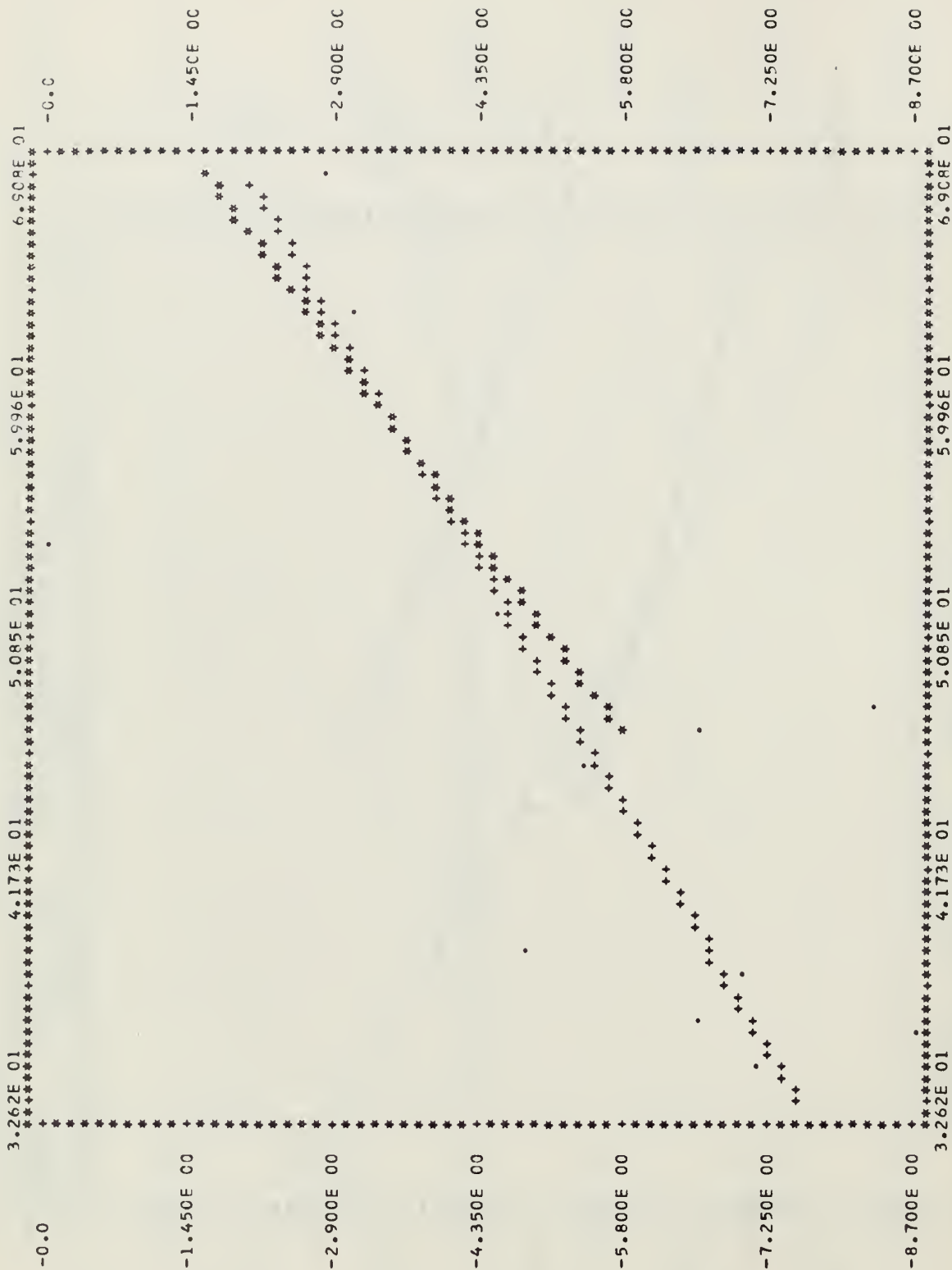
GRID POINT 4







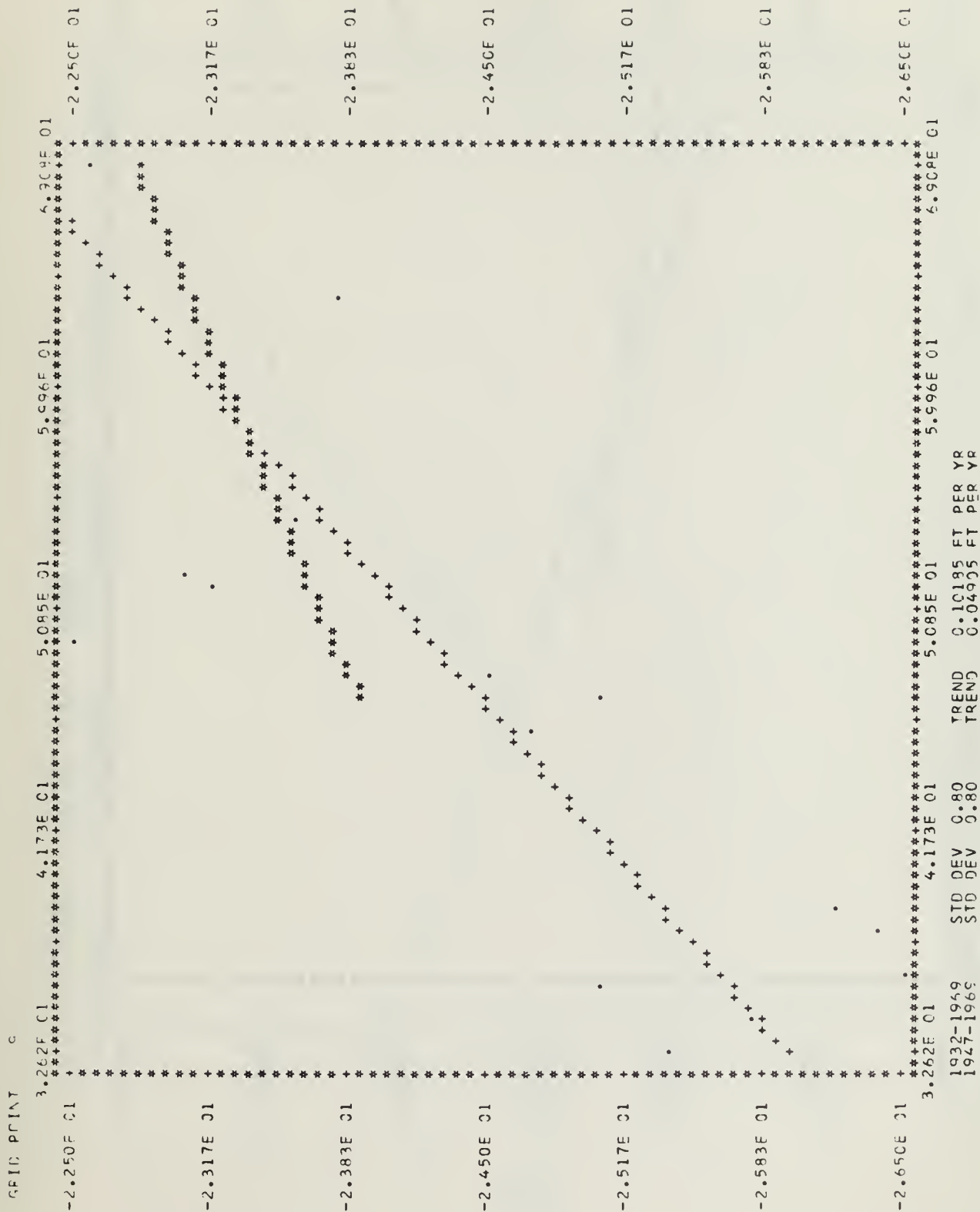
GRID POINT 6





GRID POINT 8





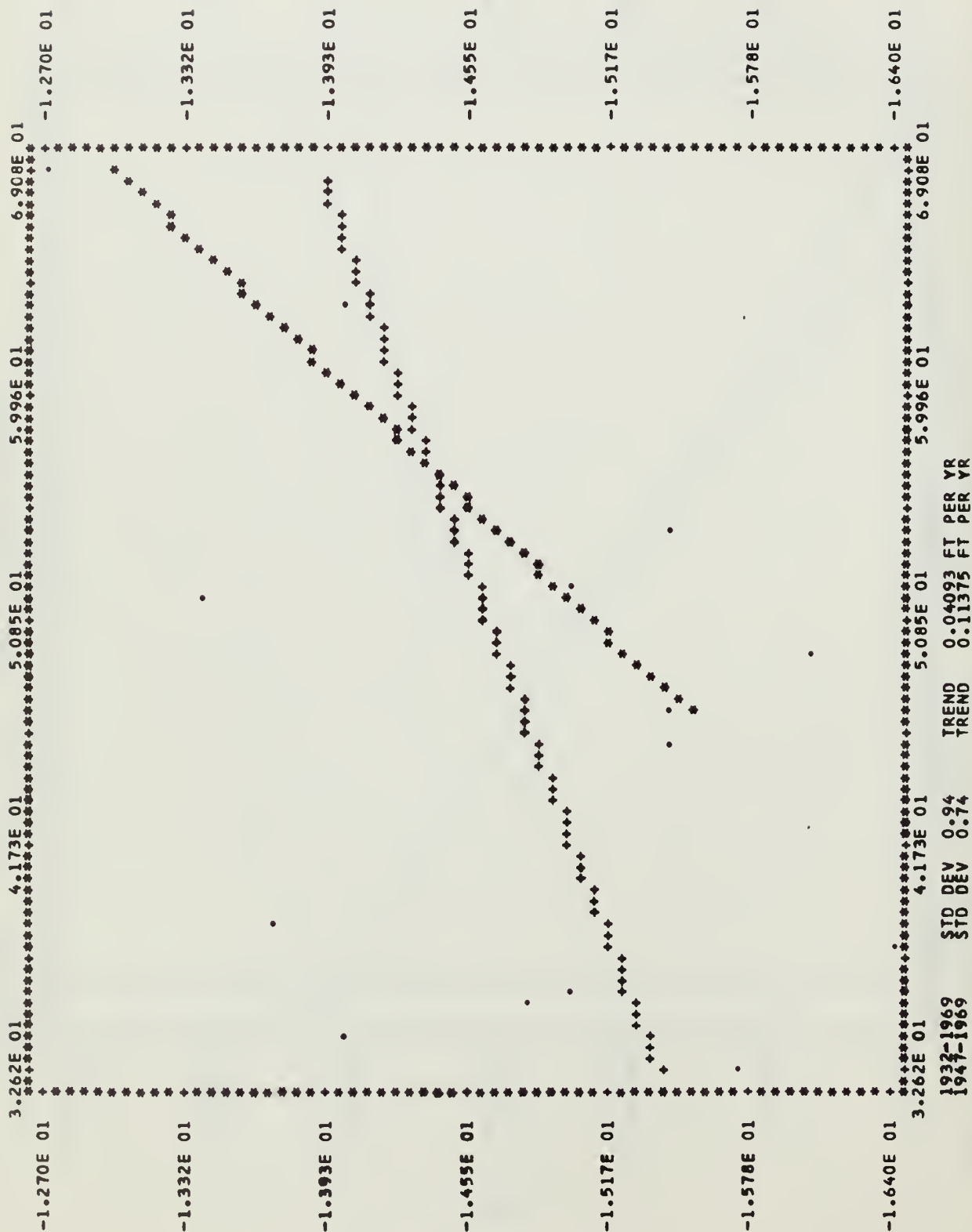


GRID POINT 10





GRID POINT 12

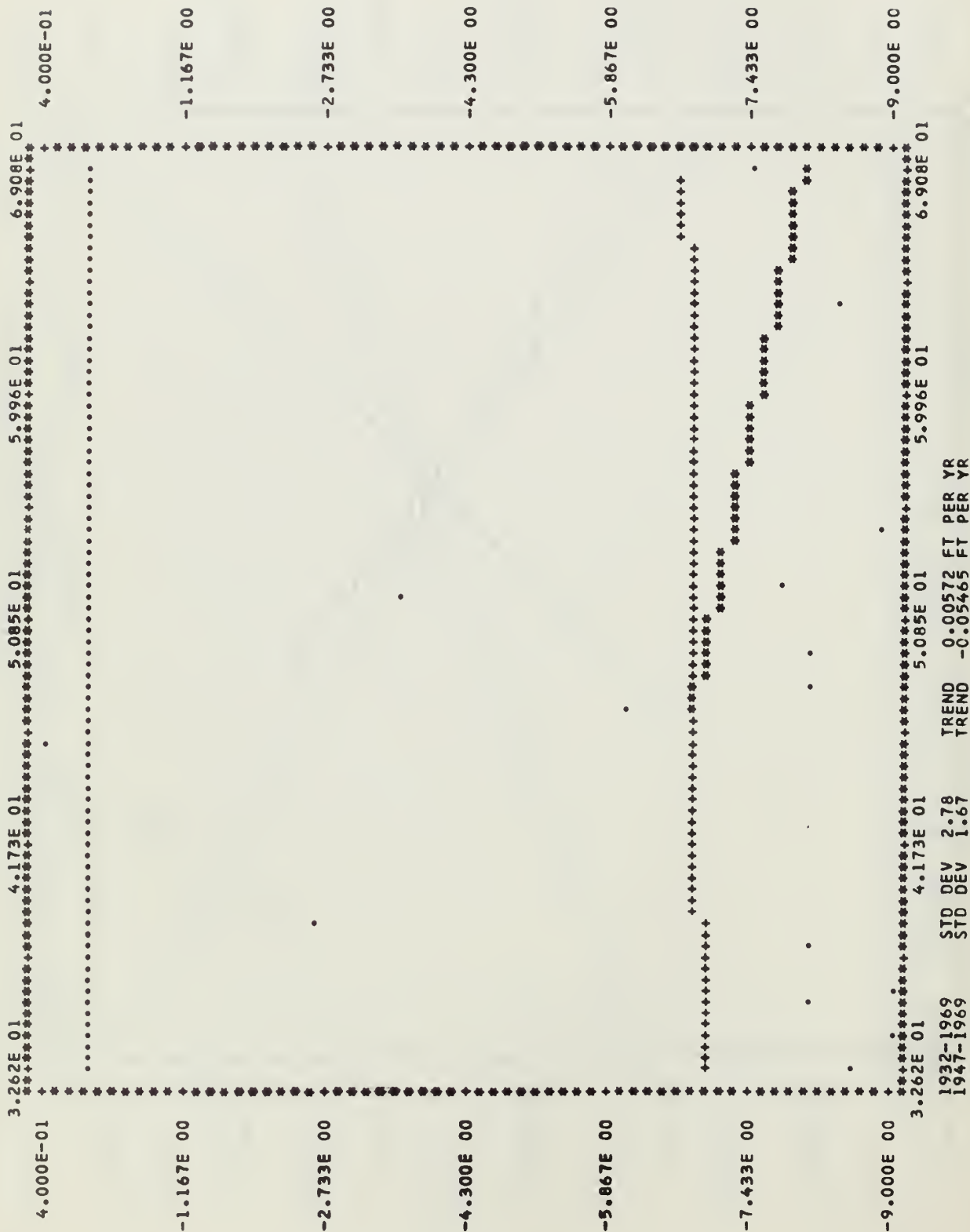


3.262E 01 4.173E 01 5.085E 01 5.996E 01 6.908E 01  
 1932-1969 1947-1969 STD DEV 0.94 STD DEV 0.74 TREND 0.04093 FT PER YR TREND 0.11375 FT PER YR

GRID POINT 13

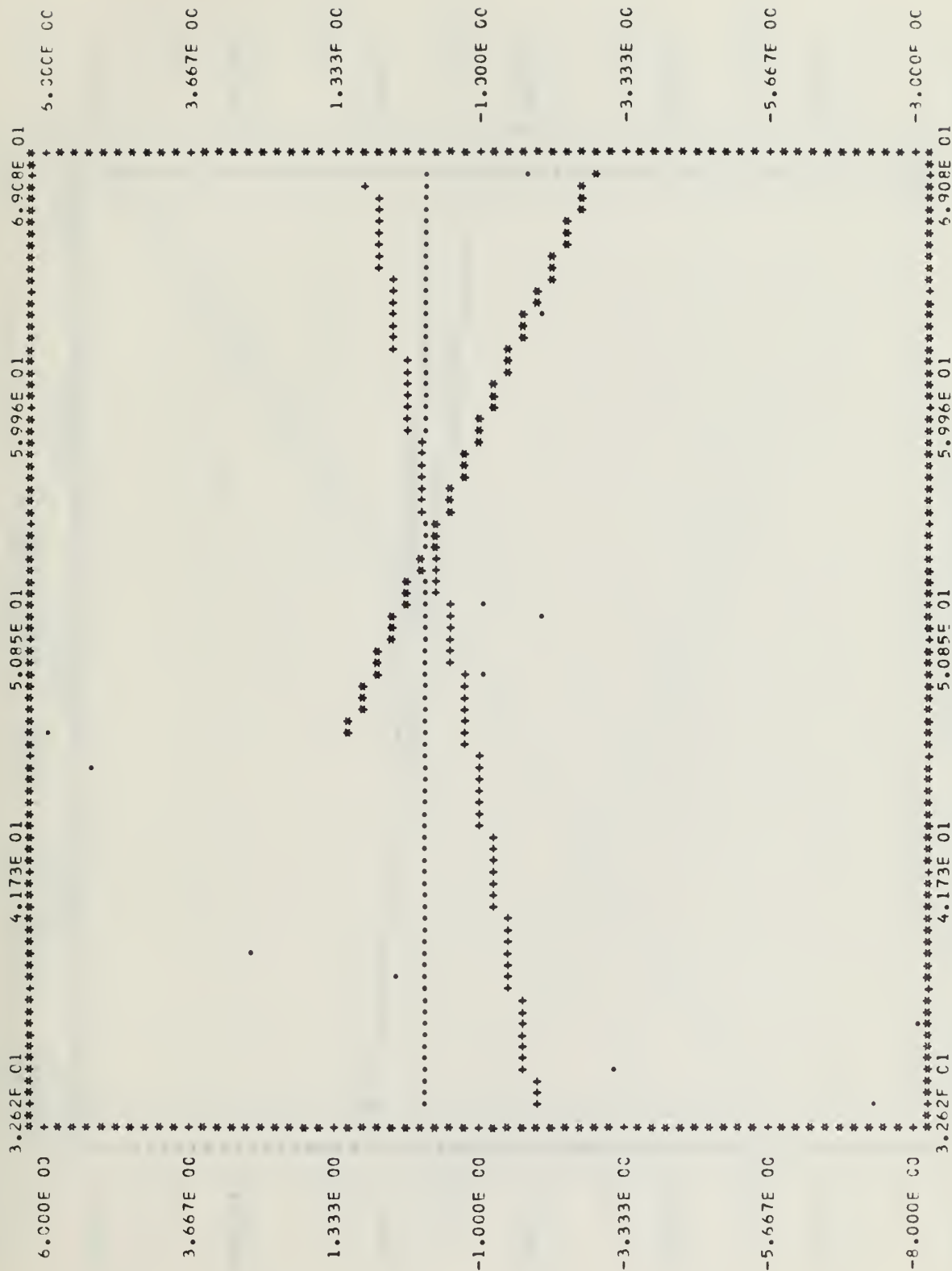


GRID POINT 14

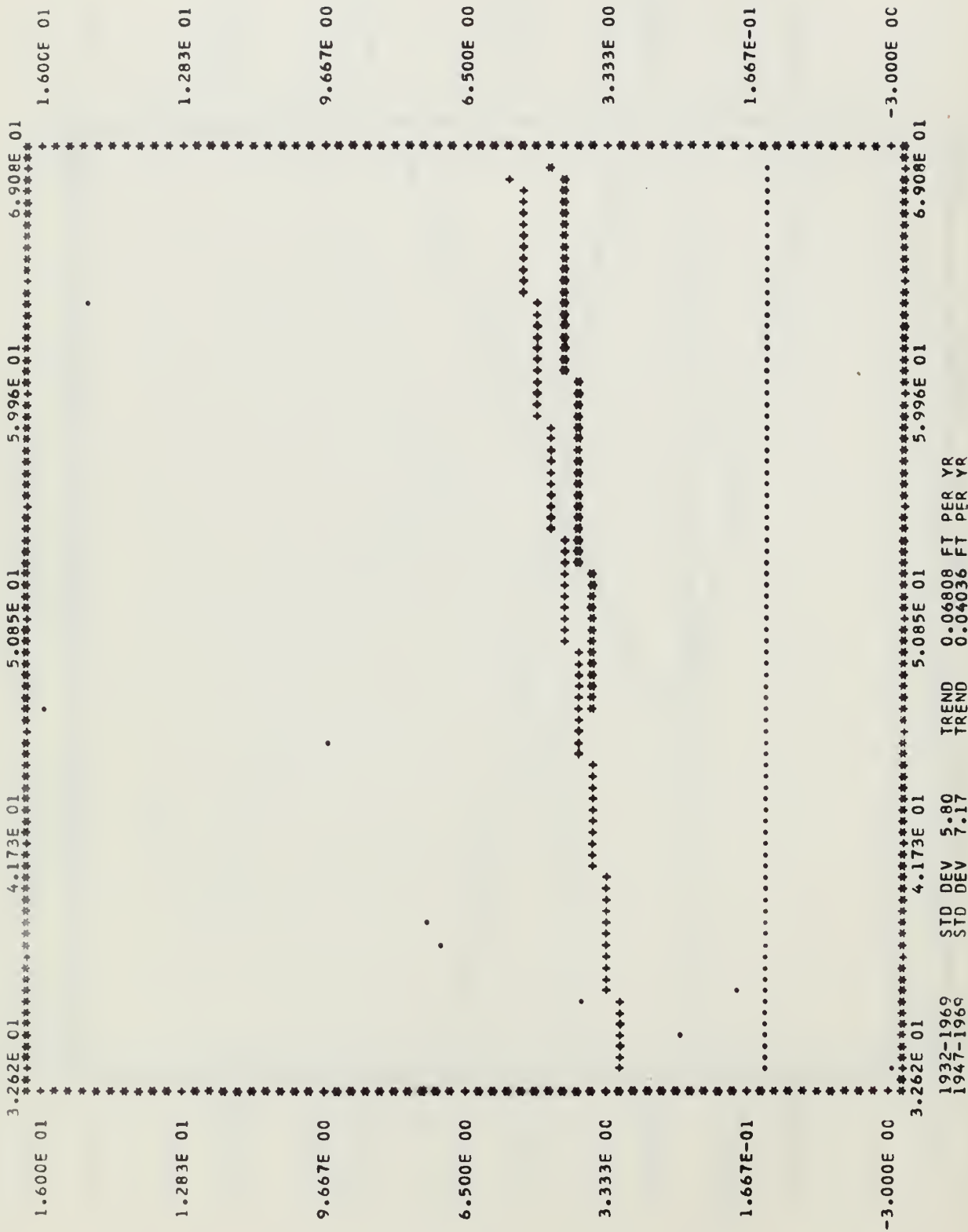




GRID PCINT 15



GRID POINT 16



GRID PCINT 17



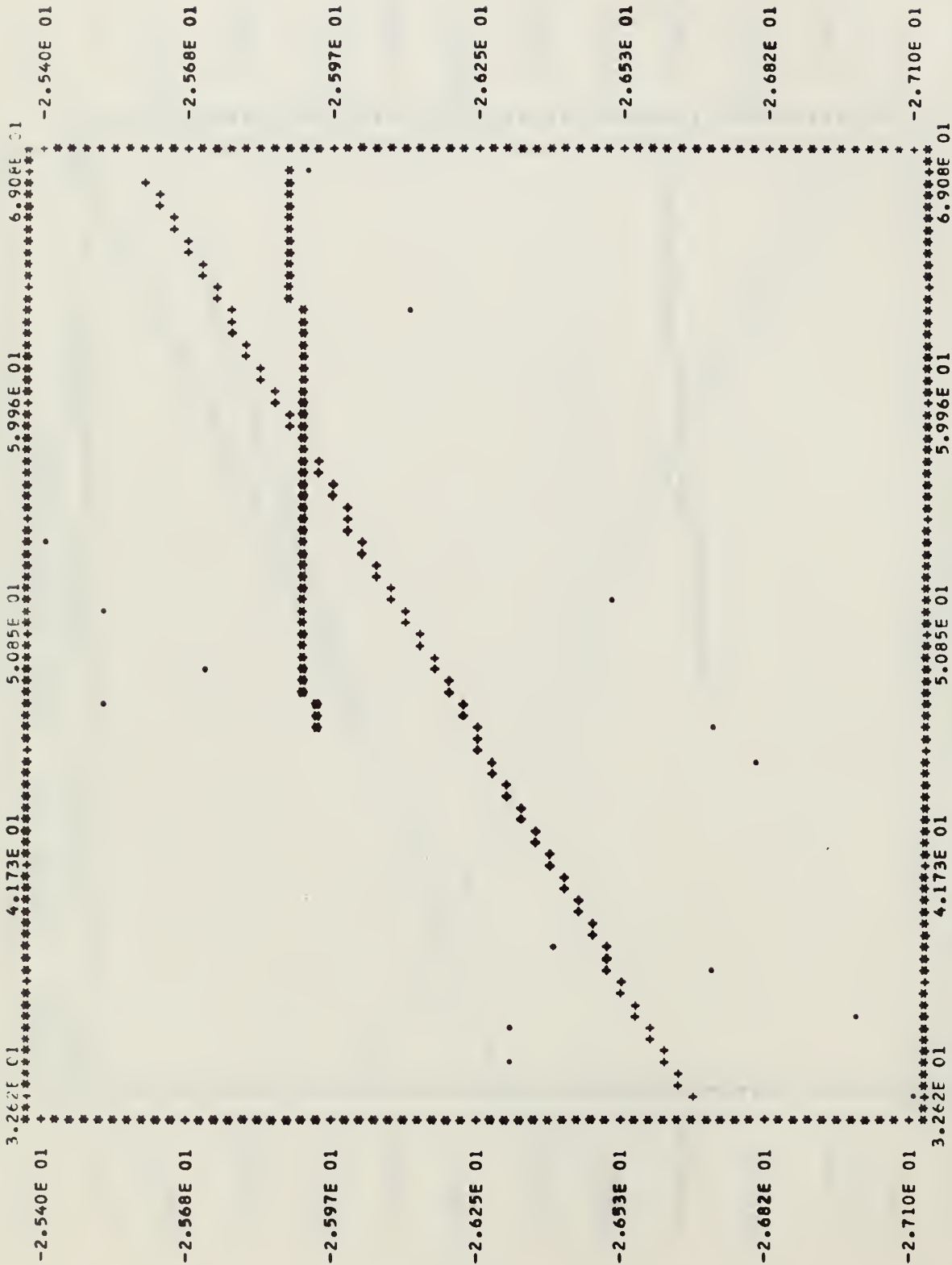
GRID POINT 18



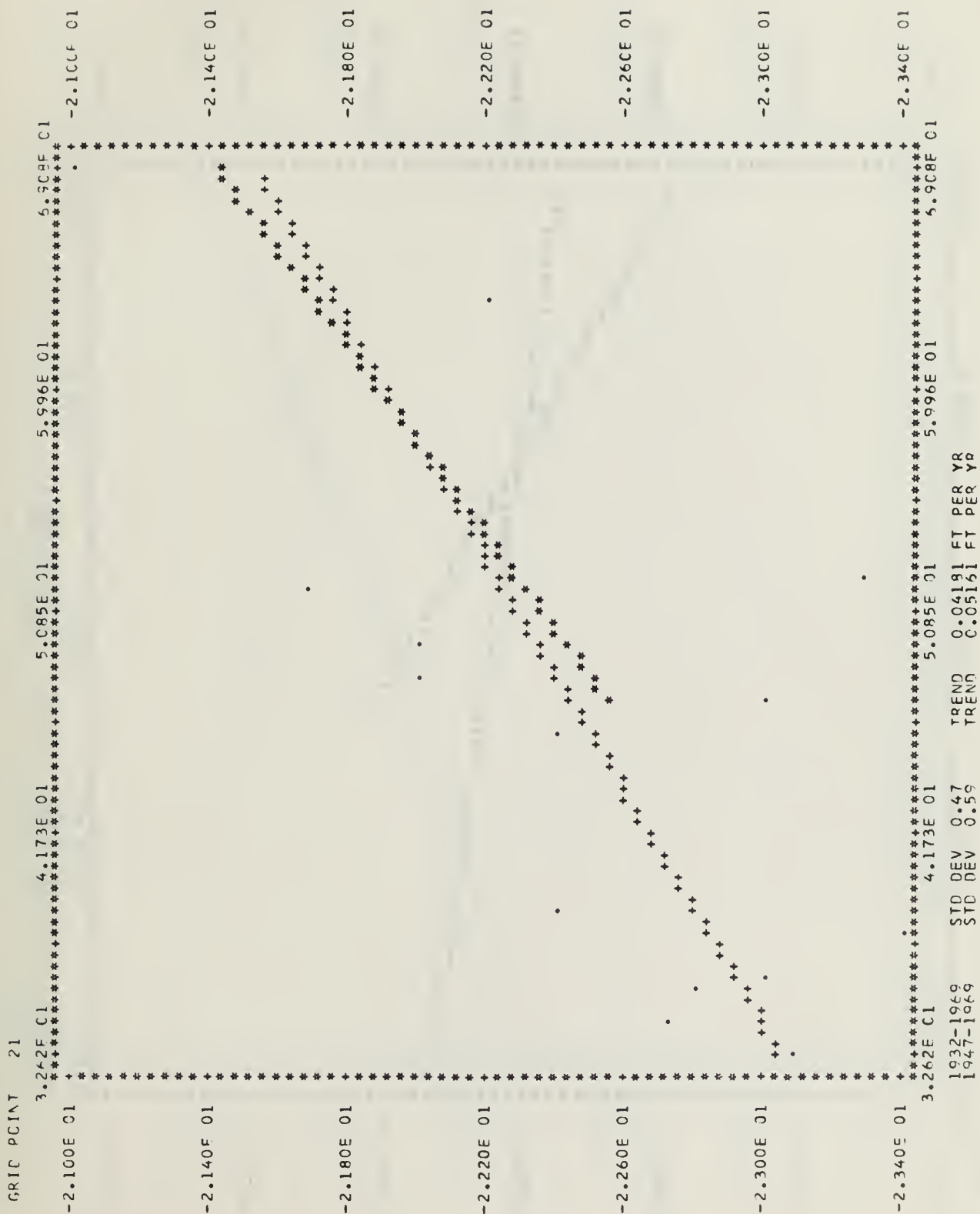
GRID PCINT 19



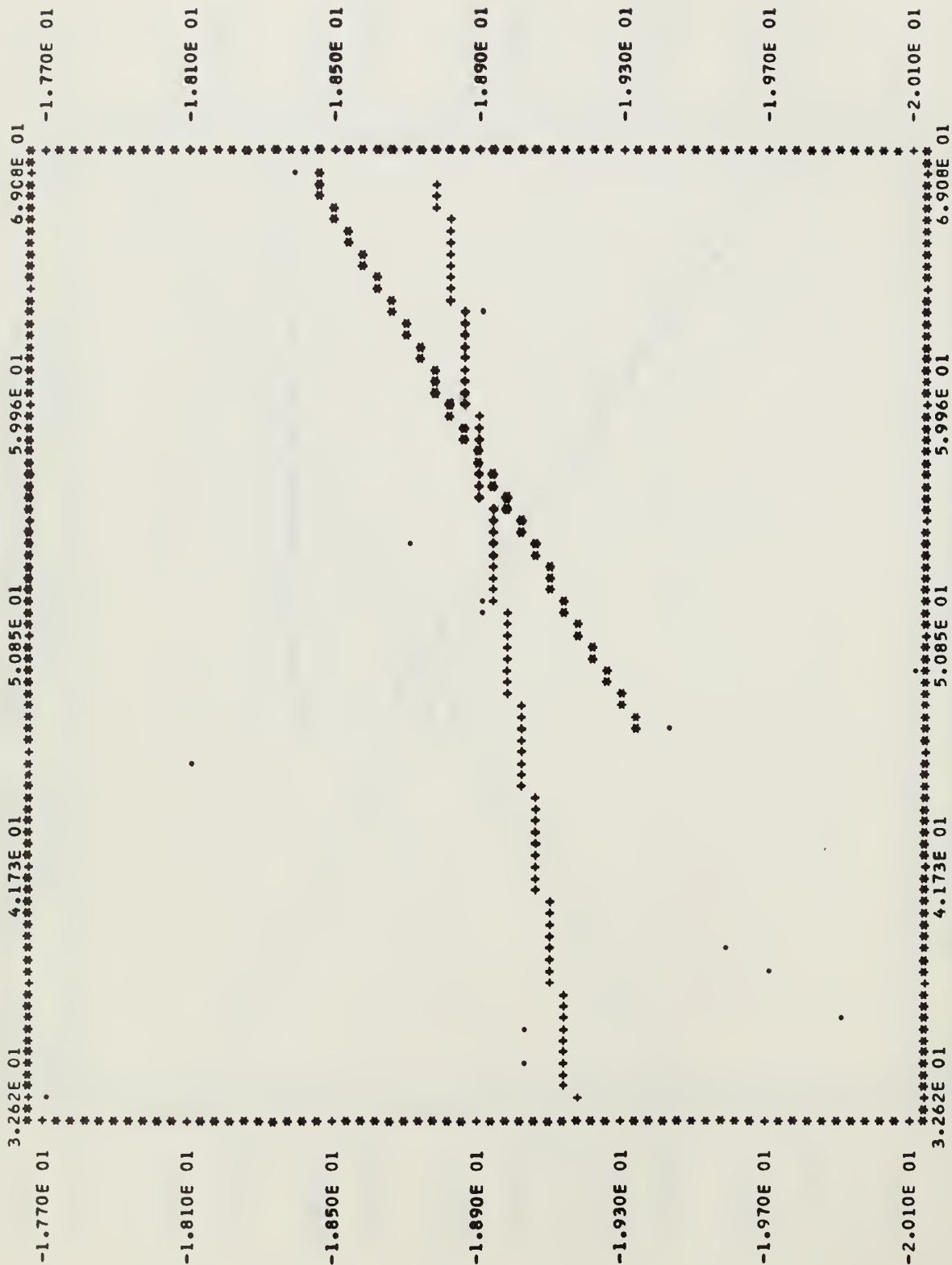




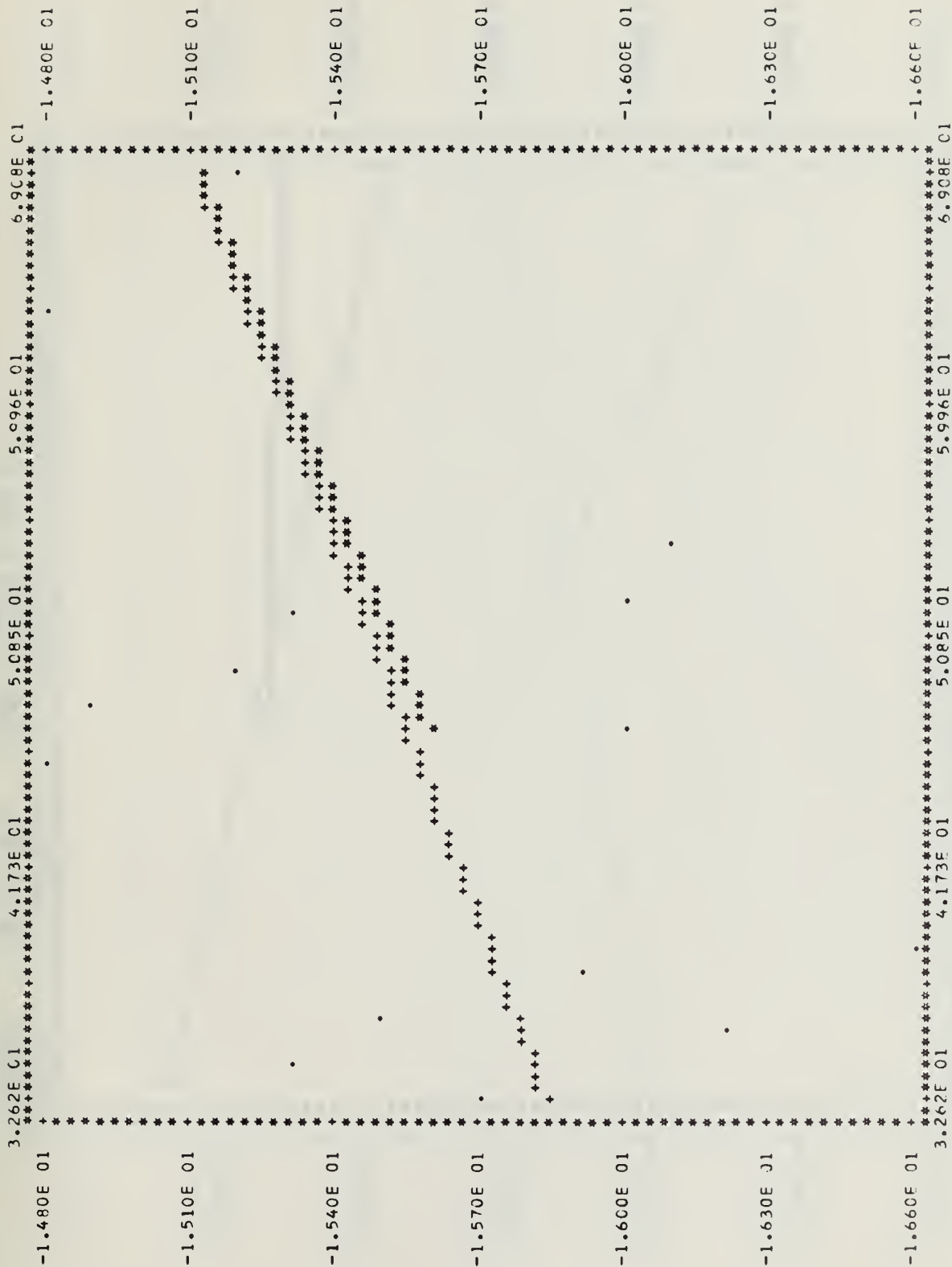
1932-1969  
1947-1969  
STD DEV 0.46  
STD DEV 0.49  
TREND 0.02941 FT PER YR  
TREND 0.00182 FT PER YR



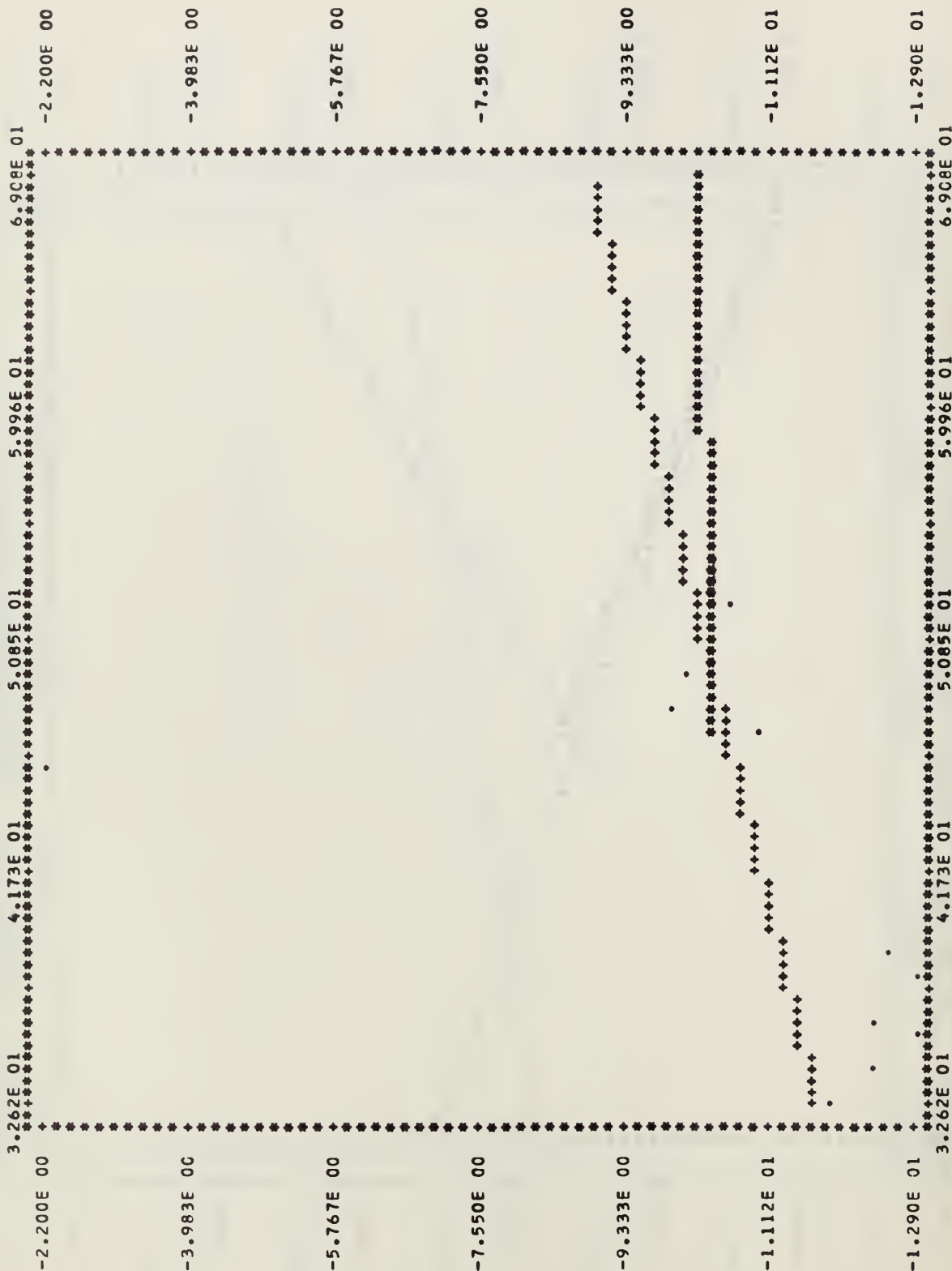
GRID PCINT 22



GRID POINT 23

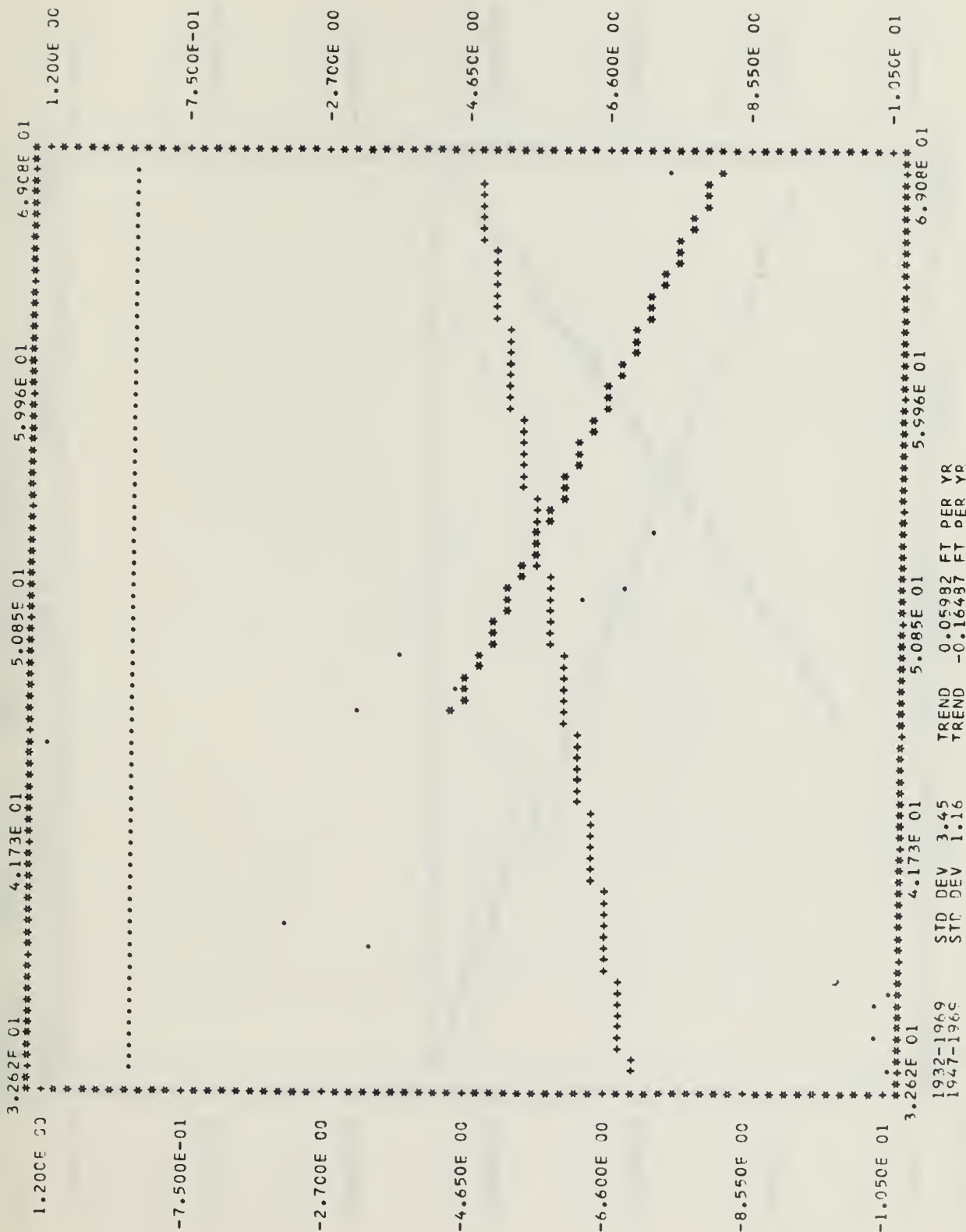


GRID POINT 24

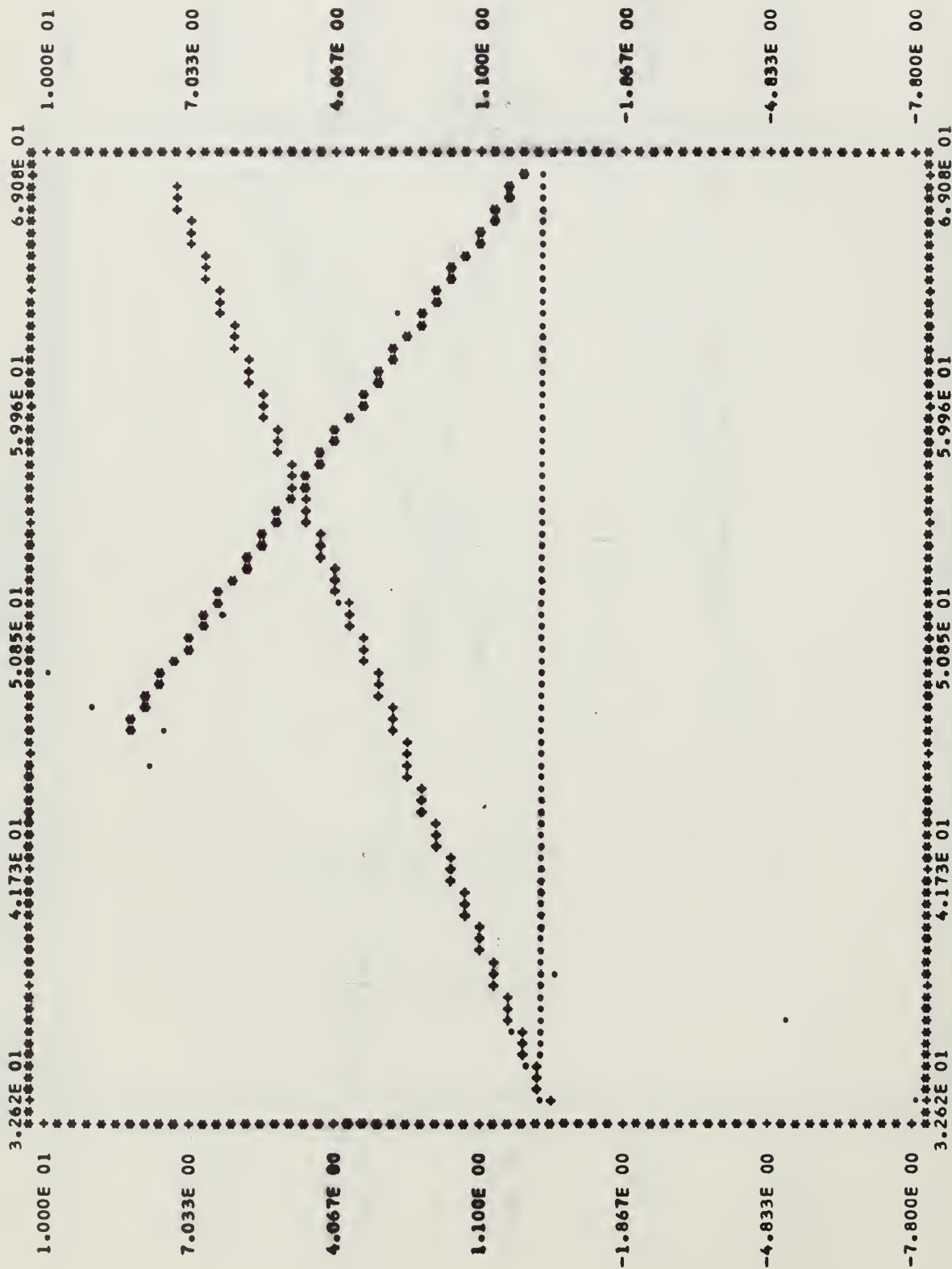


1932-1969  
1947-1969  
STD DEV 2.43  
TREND 0.07837 FT PER YR  
TREND 0.00263 FT PER YR

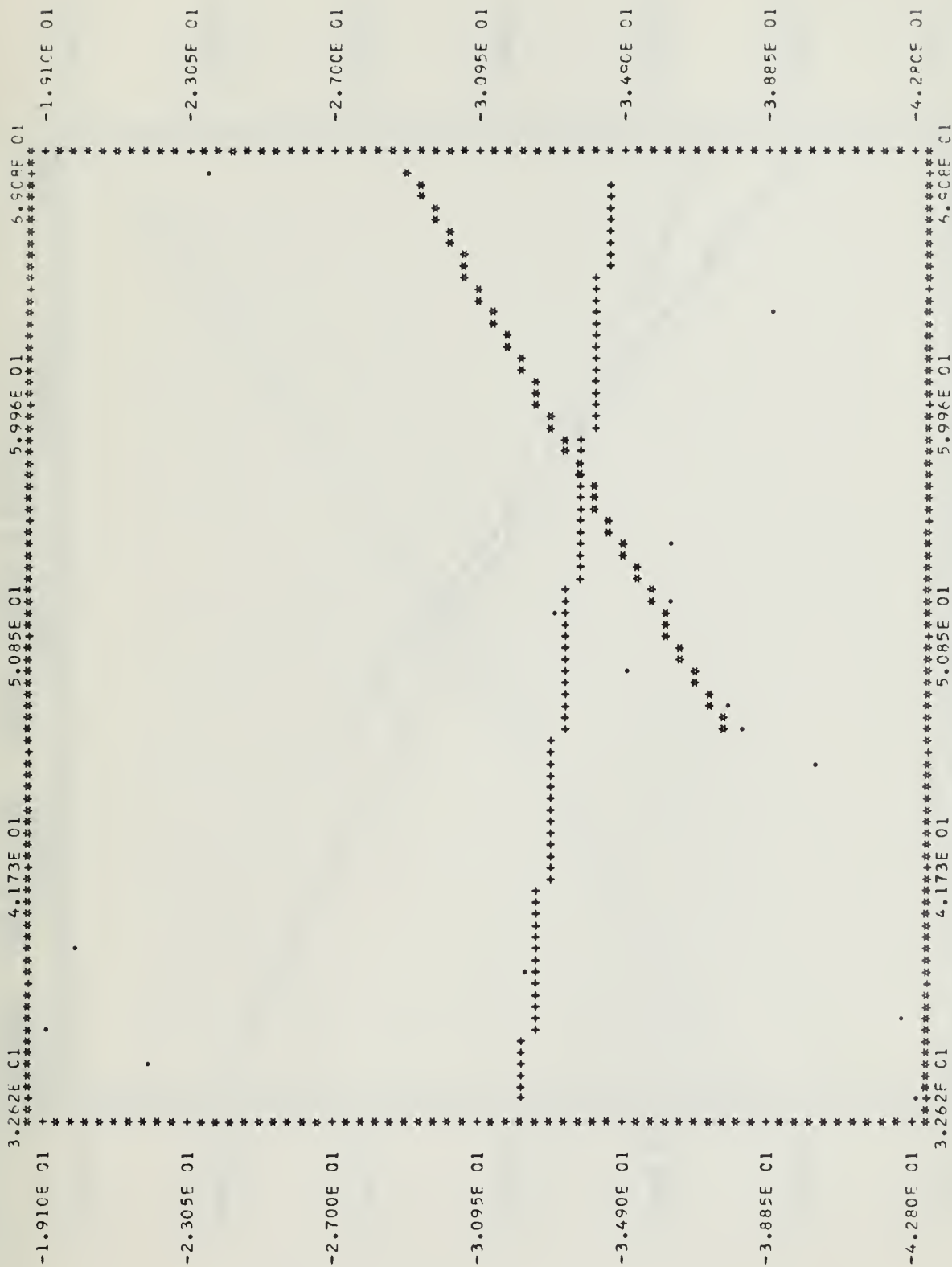




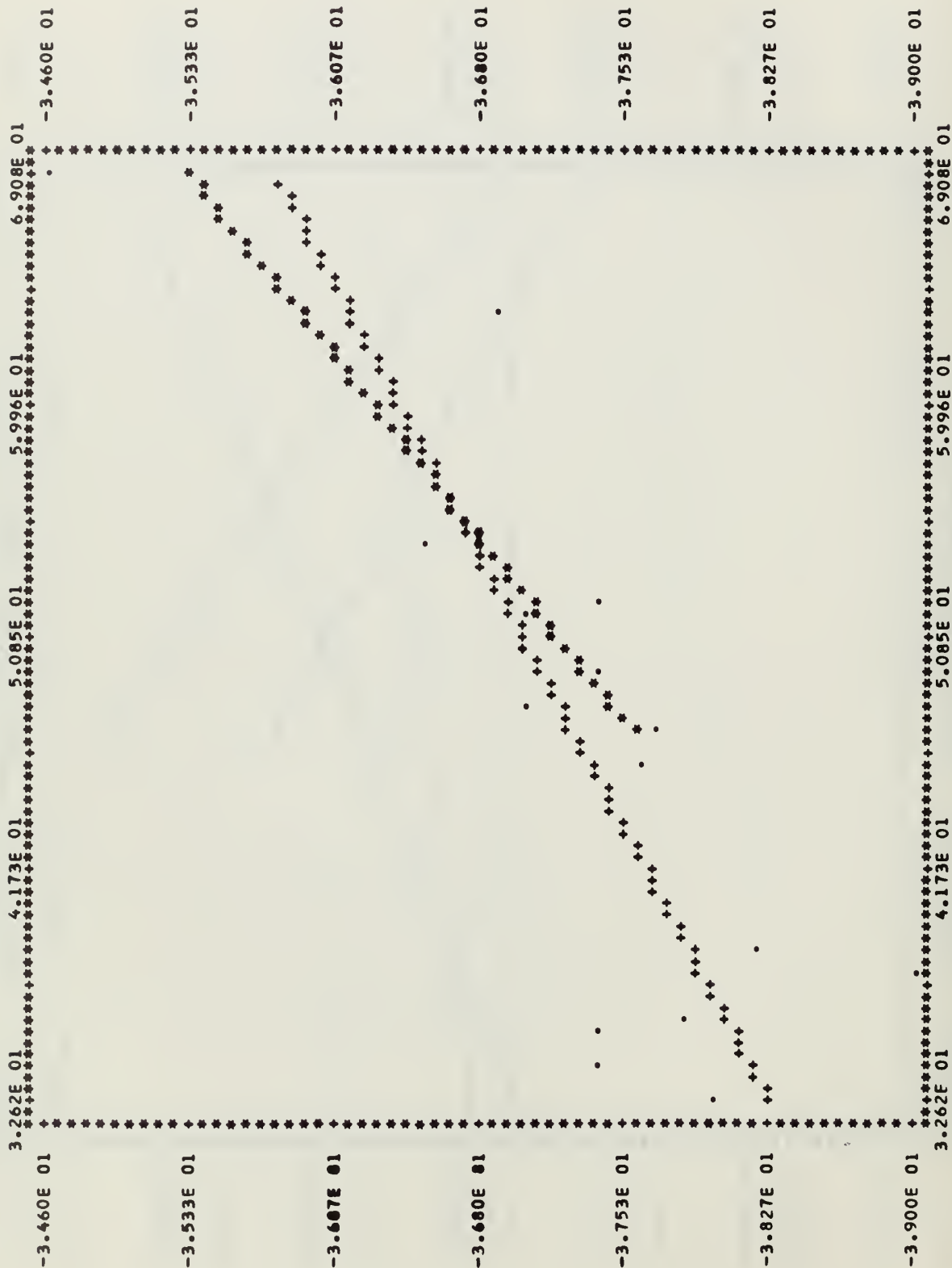
GRID POINT 26



GRID POINT 27

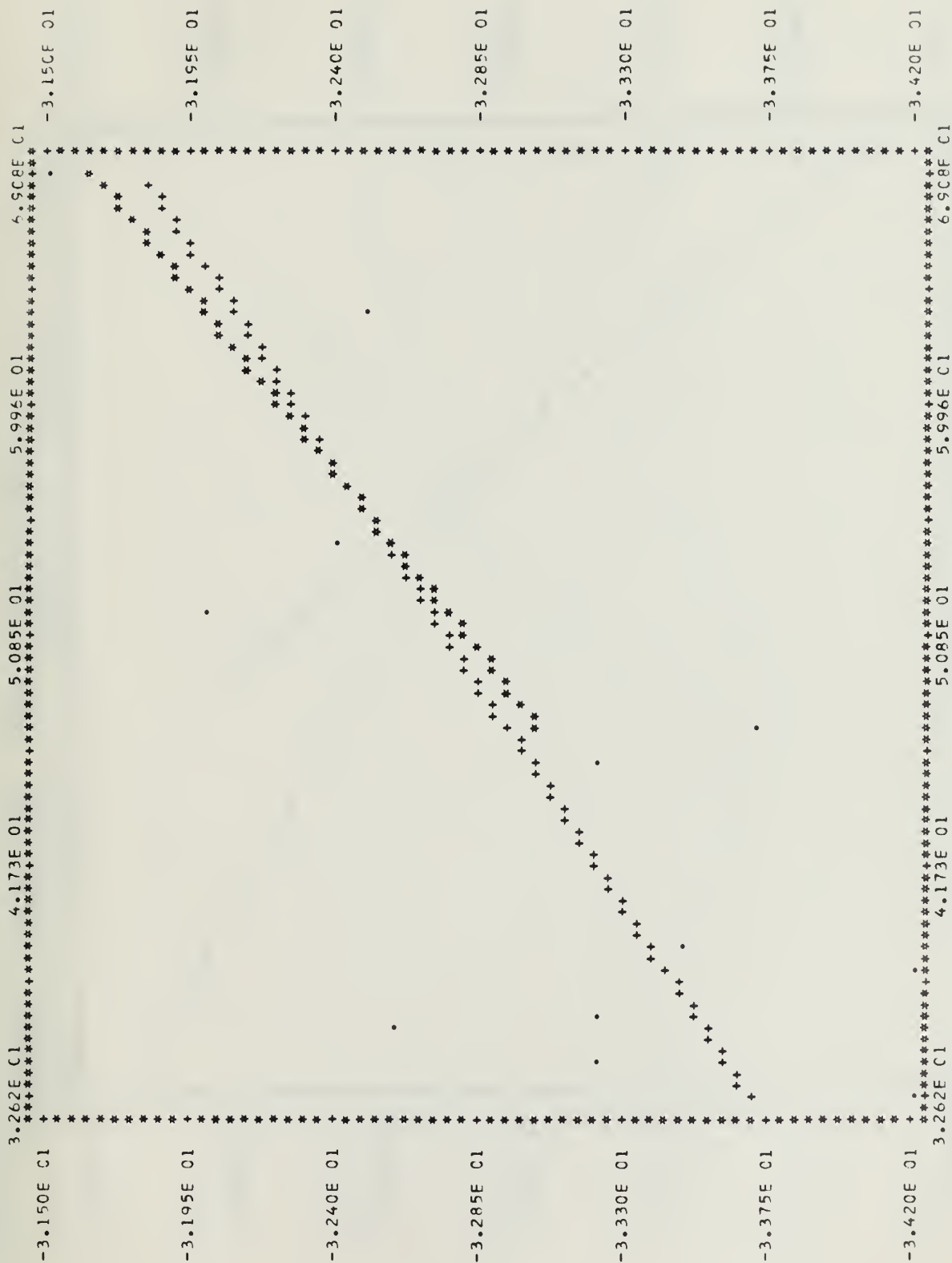


GRID POINT 28



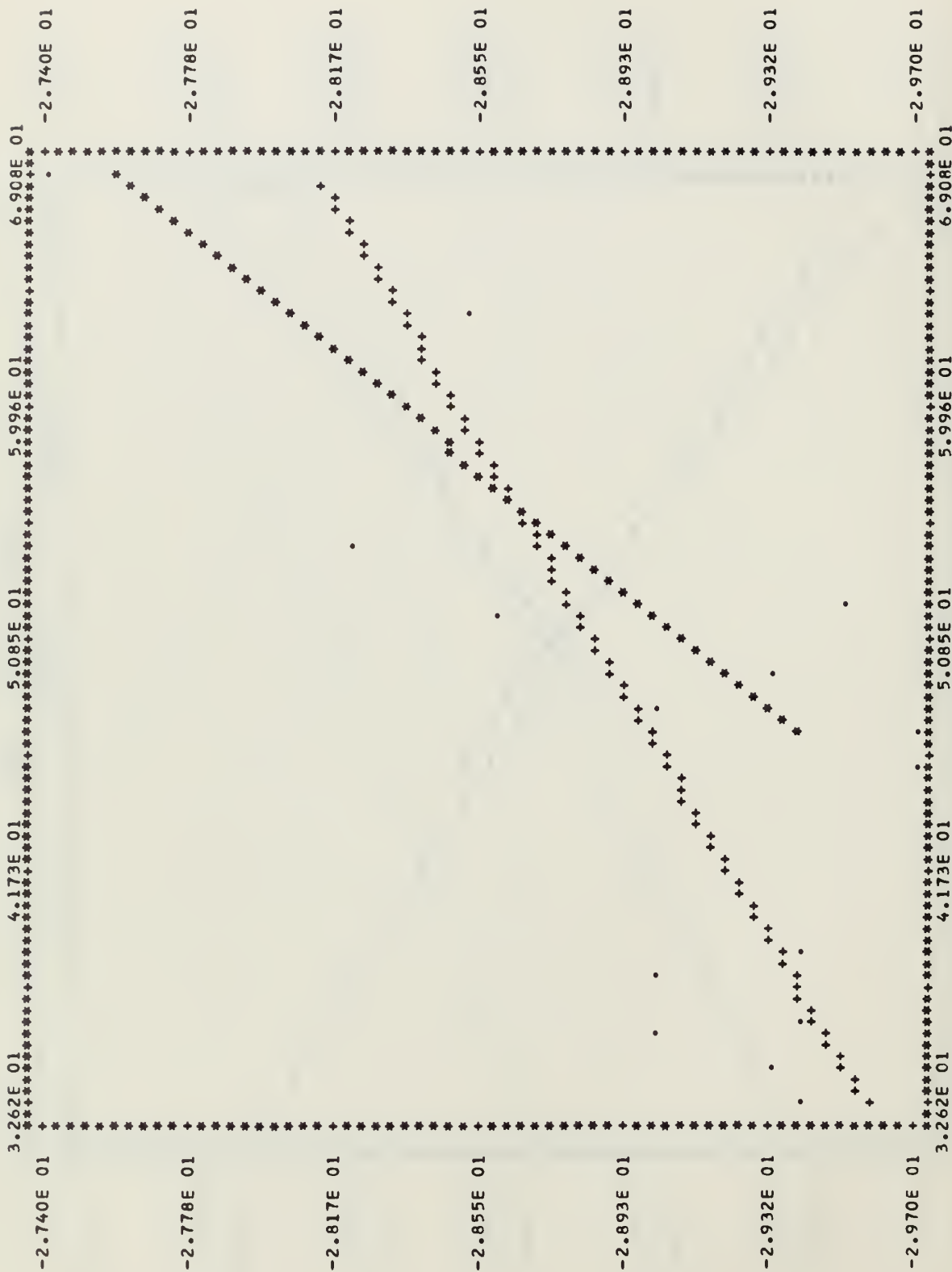
1932-1969	STD DEV	TREND	0.06916 FT PER YR
1947-1969	STD DEV	TREND	0.10269 FT PER YR

GRID POINT 29

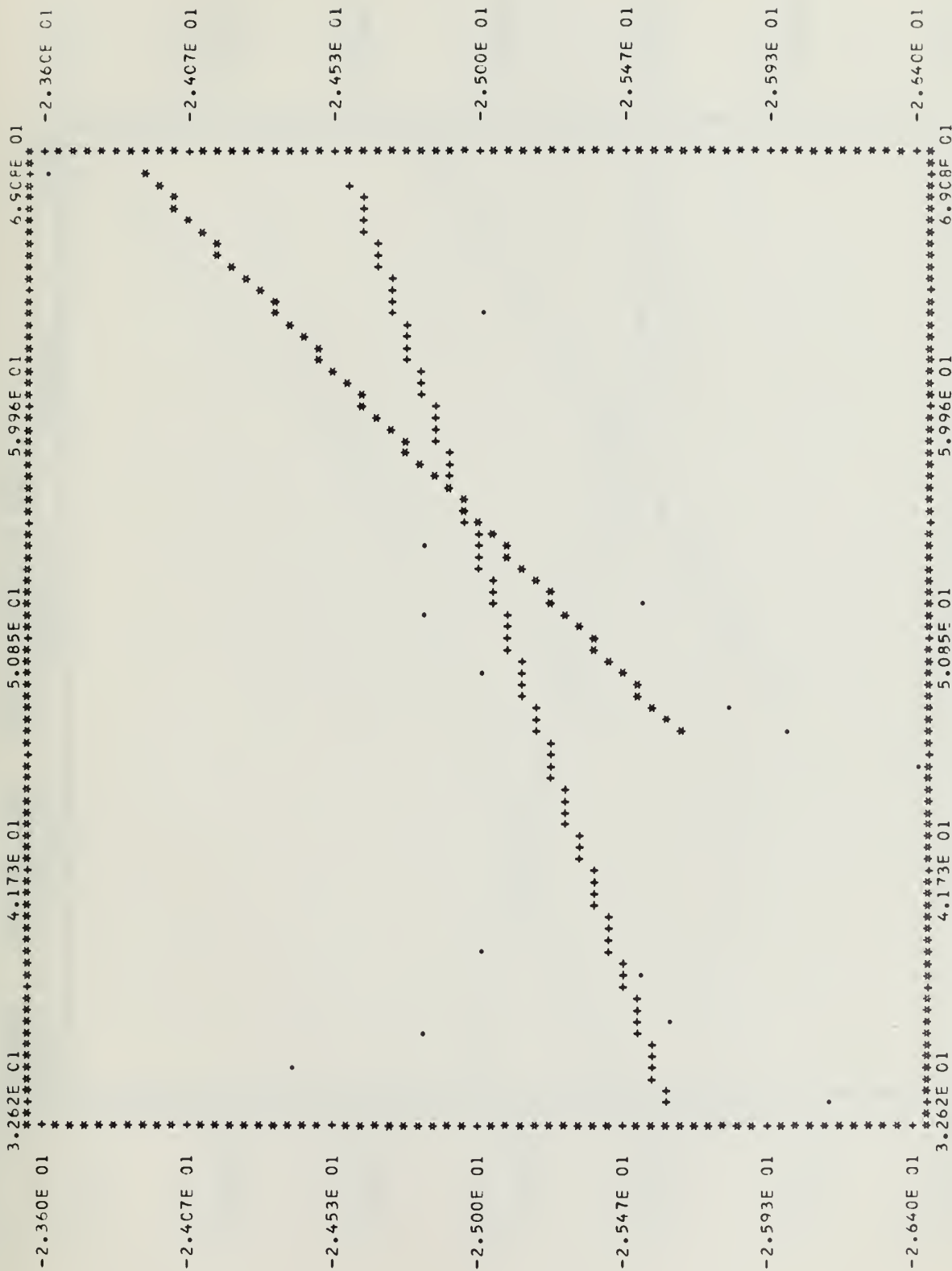




GRID PCINT 30



GRID POINT 31



TREND 0.02804 FT PER YR  
TREND 0.07817 FT PER YR

1932-1969  
1947-1979

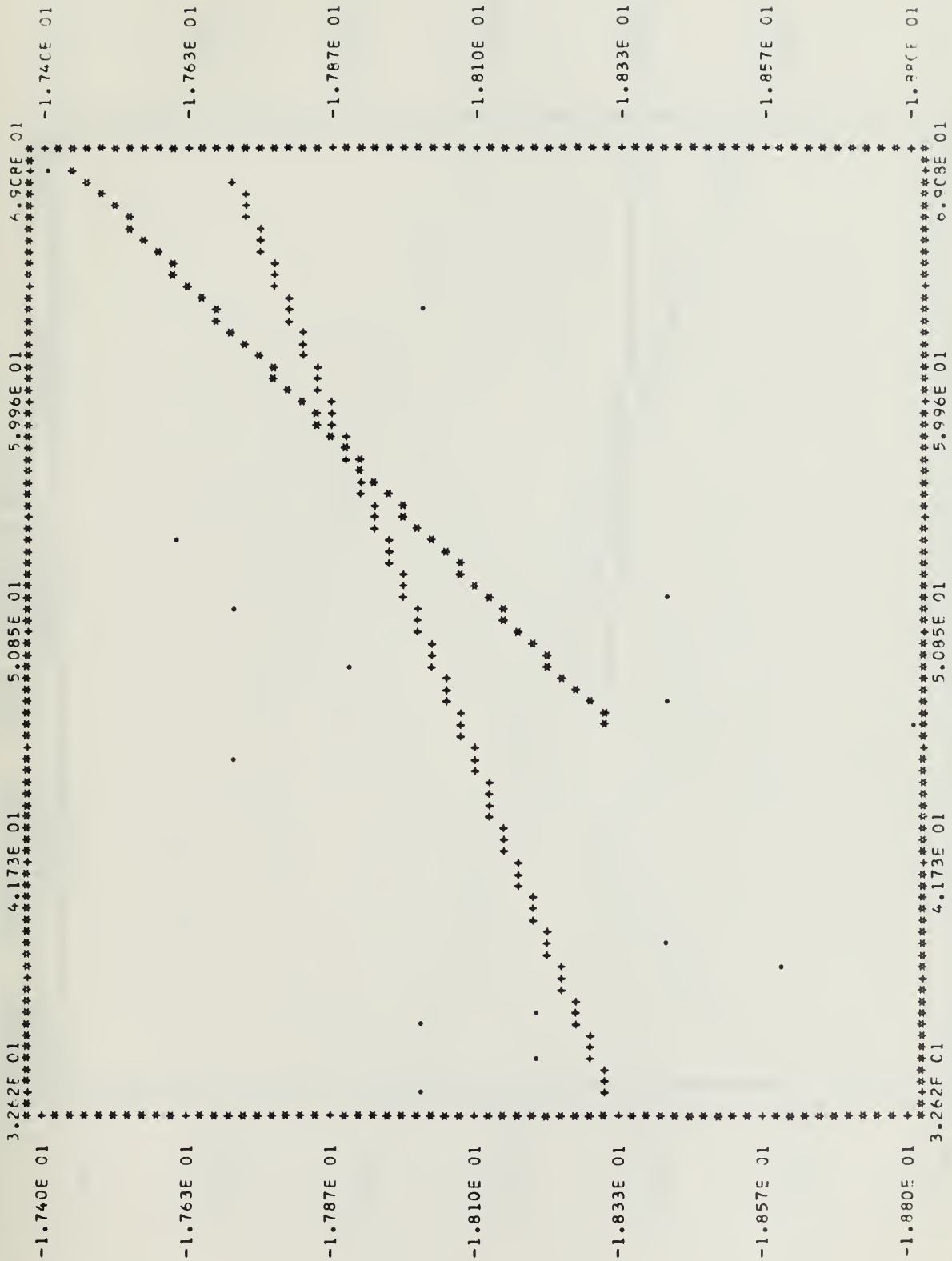
STD DEV 0.66  
STD DEV 0.43

3.262E 01 4.173E 01 5.085E 01 5.996E 01 6.908E 01

GRID POINT 32



1932-1969  
1947-1969  
STD DEV 0.40  
STD DEV 0.25  
TREND 0.00974 FT PER YR  
TREND -0.02770 FT PER YR



GRID POINT 34



1932-1969  
1947-1969  
STD DEV 0.49  
STD DEV 0.37  
TREND 0.01818 FT PER YR  
TREND 0.00379 FT PER YR





GRID POINT 36

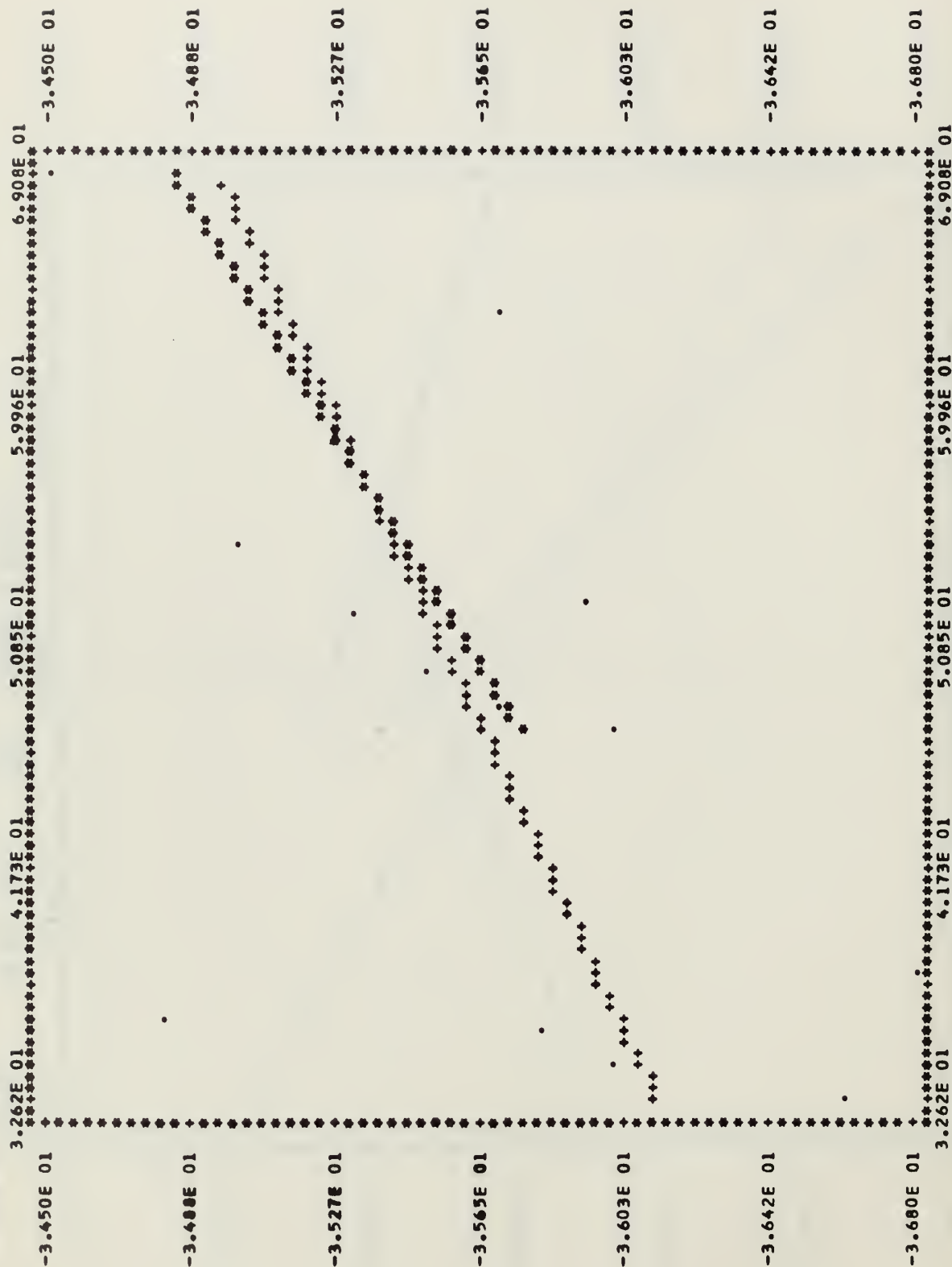


1932-1969  
1947-1969  
STD DEV 2.74  
STD DEV 1.24  
TREND 0.11872 FT PER YR  
TREND -0.09695 FT PER YR

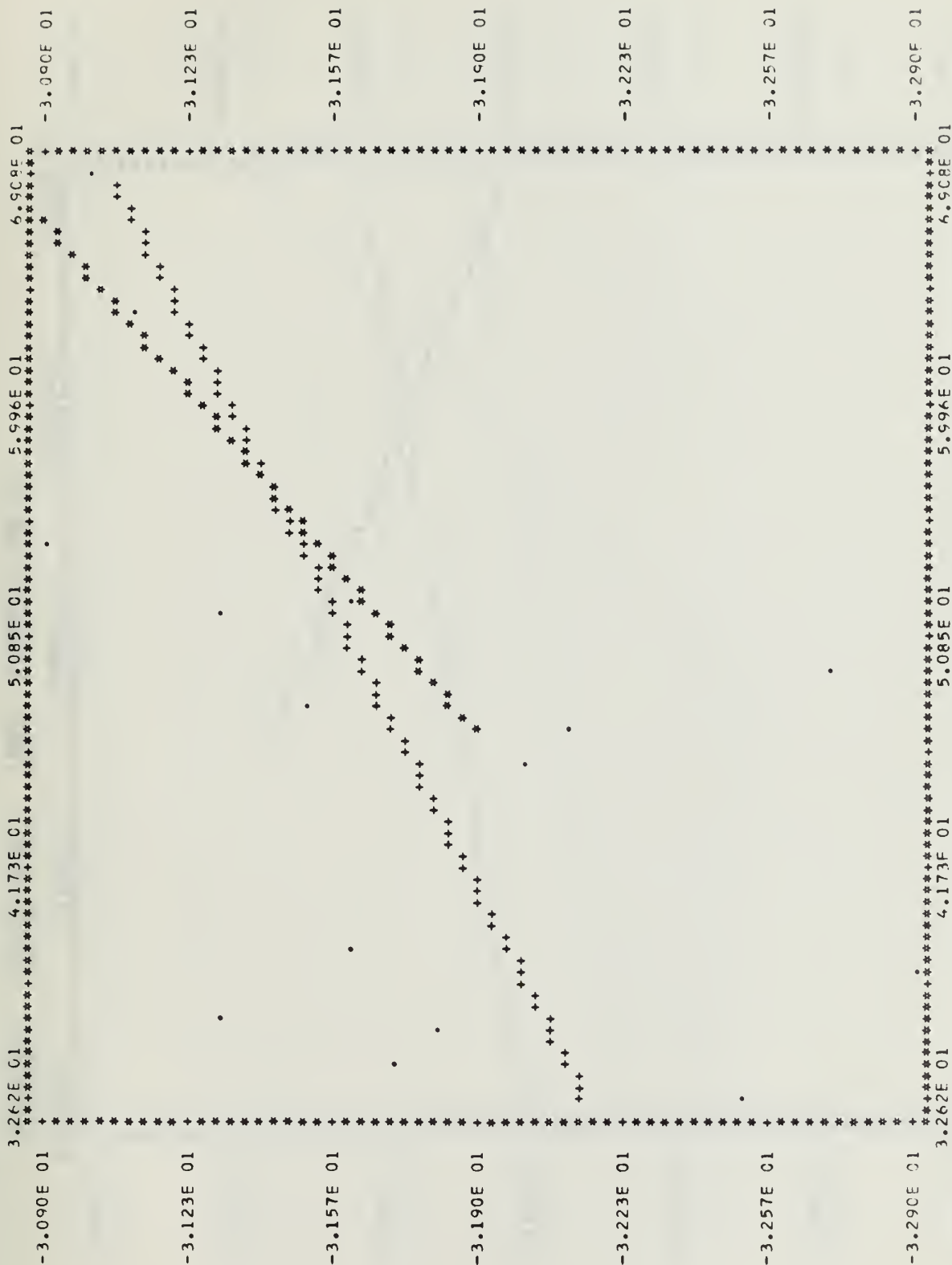
GRID POINT 37



GRID POINT 38



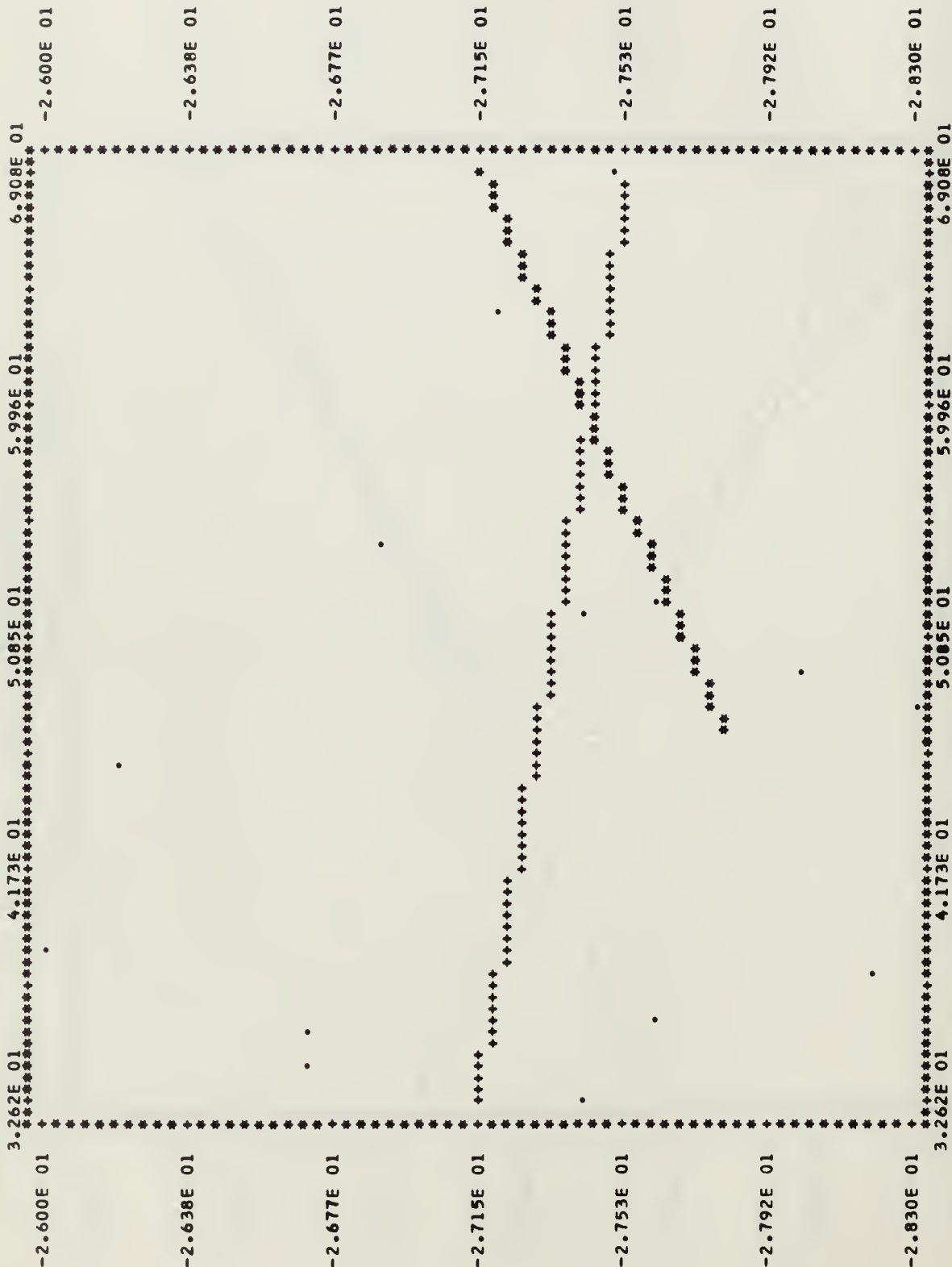
1932-1969  
1947-1969  
STD DEV 0.50  
STD DEV 0.38  
TREND 0.03189 FT PER YR  
TREND 0.04223 FT PER YR

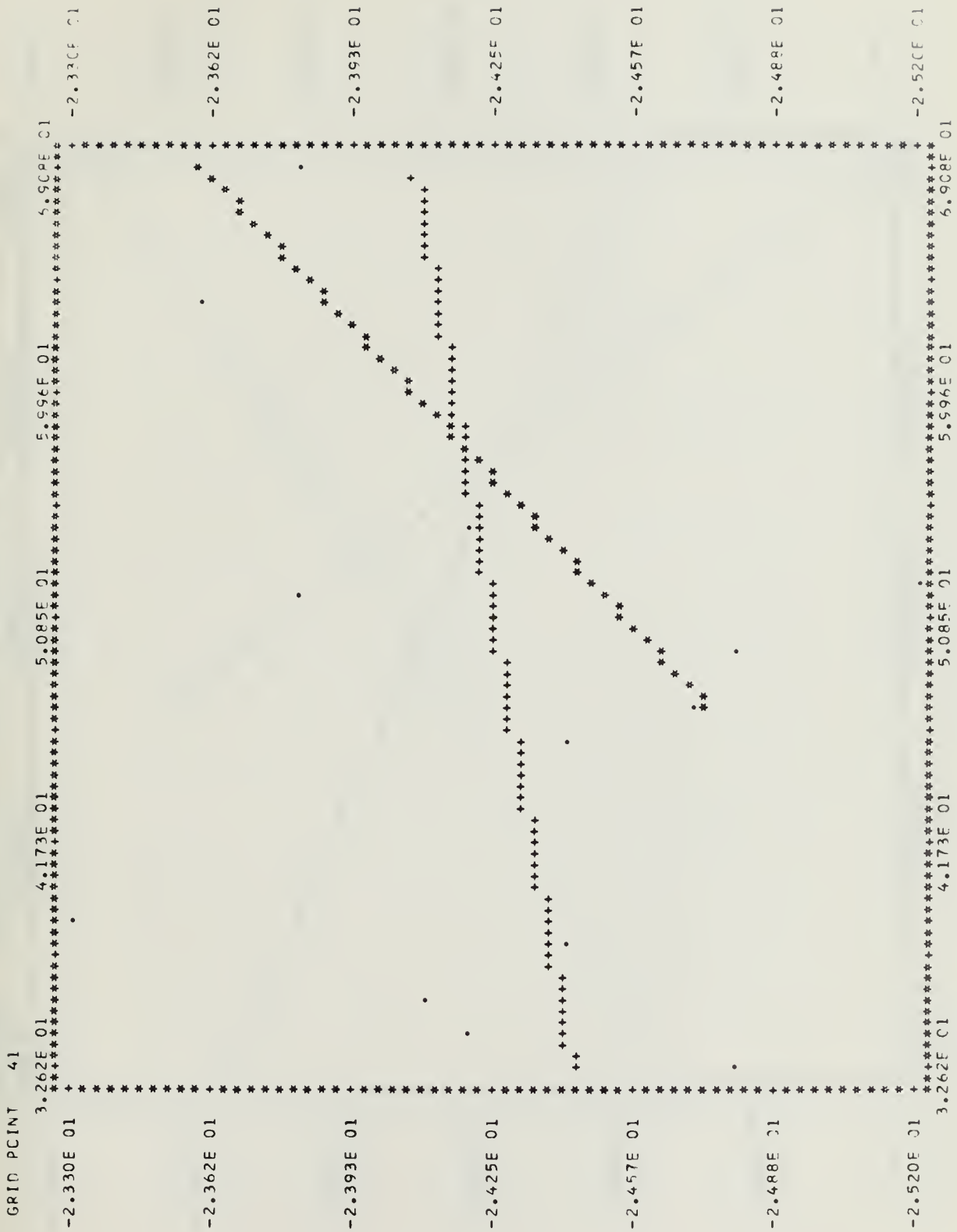


1932-1969	STD	DEV	0.51	TREND	0.03016	FT	PER	YR
1947-1969	STD	DEV	0.47	TREND	0.04933	FT	PER	YR



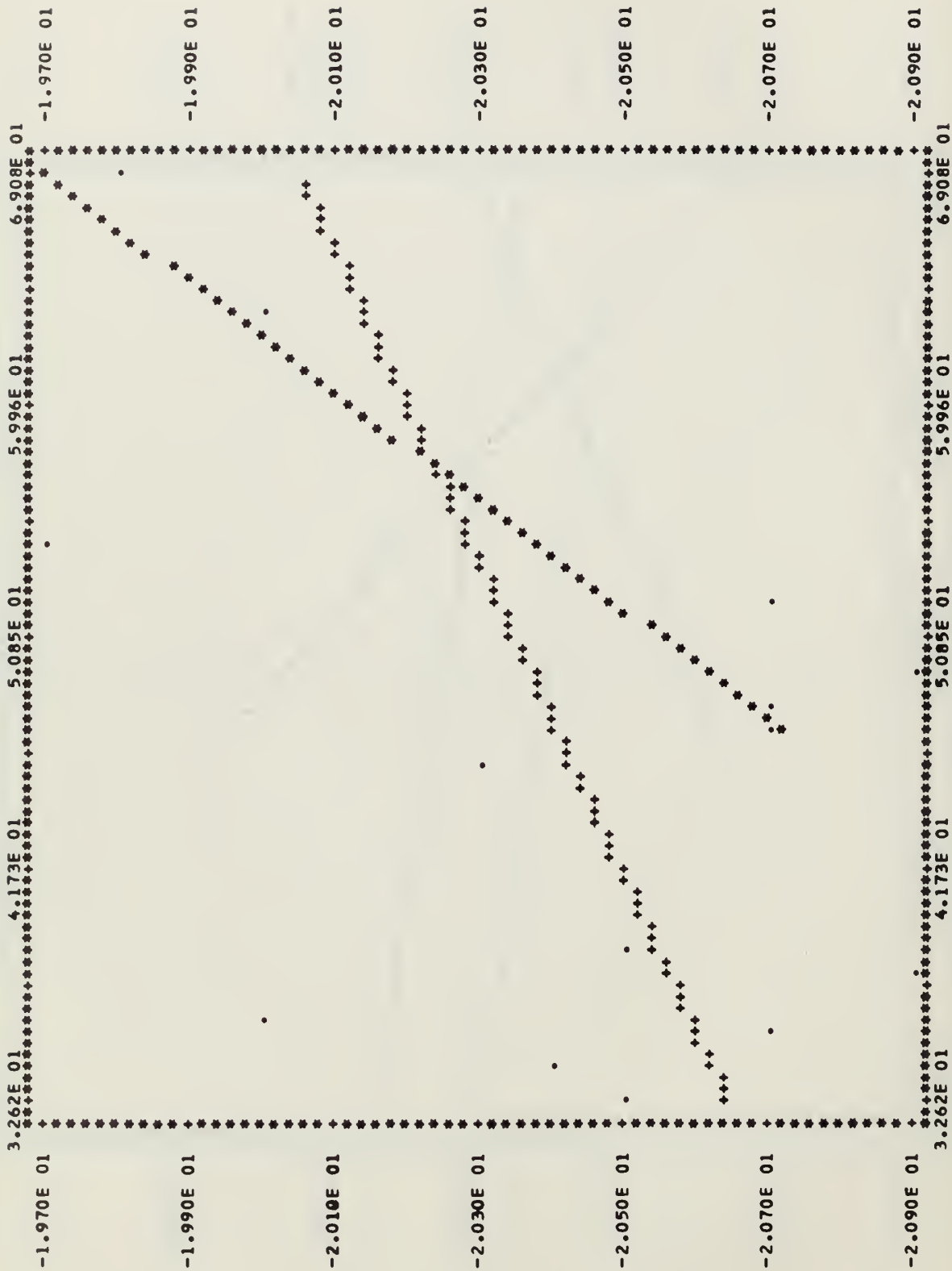
GRID POINT 40





1932-1969  
 1927-1969  
 STD DEV 0.50  
 STD DEV 0.41  
 TREND 0.00998 FT PER YR  
 TREND 0.05189 FT PER YR

GRID POINT 42









## APPENDIX D

### LIST OF CHARTS OF MONTEREY HARBOR: 1851 to 1969

A list of the 56 hydrographic charts examined during the course of this study are presented herein. The charts marked with an asterisk (\*) are those used for the surveys shown in Appendix A and for the comparisons shown in Appendix B.

LIST OF CHARTS OF MONTEREY HARBOR: 1856 to 1969

Corps of Engineers, U. S. Army, 1927  
Re-examination of Monterey Harbor, California  
Dwg. No. 6-2-10

Corps of Engineers, U. S. Army, 1928  
Resurvey of Monterey Harbor, California  
Dwg. No. 6-2-11

Corps of Engineers, U. S. Army, 1931  
Breakwater at Monterey Harbor, California  
Dwg. No. 6-9-5

Corps of Engineers, U. S. Army, 1932\*  
Monterey Harbor, California  
Dwg. No. 6-2-12, 3 sheets

Corps of Engineers, U. S. Army, 1934  
Monterey Harbor, California  
Comparison of depth contours, Surveys of Oct 1931 and Mar 1934  
Dwg. No. 6-20-8

Corps of Engineers, U. S. Army, 1935\*  
Survey of March 14-15 1934, Monterey Harbor  
Dwg. No. 6-2-13

Corps of Engineers, U. S. Army, 1935\*  
Survey of July 29-31 1935, Monterey Harbor, California  
Dwg. No. 6-2-14

Corps of Engineers, U. S. Army, 1935\*  
Survey of Oct 2-5 1935, Monterey Harbor, California  
Dwg. No. 6-2-15

Corps of Engineers, U. S. Army, 1937\*  
Annual Survey, Monterey Harbor, California  
Dwg. No. 6-2-16

Corps of Engineers, U. S. Army, 1938  
Monterey Harbor, California Dwg. No. 6-1-23

Corps of Engineers, U. S. Army, 1938\*  
Survey of July 1938, Monterey Harbor, California  
Dwg. No. 6-2-17

Corps of Engineers, U. S. Army, 1939  
Monterey Harbor, California  
Dwg. No. 6-1-24

Corps of Engineers, U. S. Army, 1945\*  
Monterey Harbor, Survey of Nov 27-Dec 1 1945  
Dwg. No. 6-9

Corps of Engineers, U. S. Army, 1946  
Monterey Harbor Dredging  
Dwg. No. 6-1-32

Corps of Engineers, U. S. Army, 1947\*  
Monterey Harbor condition survey of Jan-Feb 1947  
Dwg. No. 6-12

Corps of Engineers, U. S. Army, 1947  
Monterey Harbor, After dredging survey of 4-12 Feb 1947  
Dwg. No. 6-1-33

Corps of Engineers, U. S. Army, 1947  
Monterey Harbor, Jet probings in harbor area and  
soundings adjacent to breakwater  
Dwg. No. 6-13

Corps of Engineers, U. S. Army, 1947  
Monterey Harbor project condition survey of 4 April 1947  
Dwg. No. 6-2-20

Corps of Engineers, U. S. Army, 1948\*  
Monterey Harbor condition survey of 6-12 Feb 1948  
Dwg. No. 6-14 and 6-2-21

Corps of Engineers, U. S. Army, 1949  
Monterey Harbor condition survey of 21-23 June 1949  
Dwg. No. 6-17

Corps of Engineers, U. S. Army, 1949\*  
Monterey Harbor condition survey of 21, 22 & 23 June 1949  
Dwg. No. 6-18 and 6-2-22

Corps of Engineers, U. S. Army, 1950  
Monterey Harbor dredging  
Dwg. No. 6-1-35

Corps of Engineers, U. S. Army, 1950  
Monterey Harbor, before dredging survey of 28-29 April 1950  
Dwg. No. 6-20

Corps of Engineers, U. S. Army, 1950  
Monterey Harbor, After dredging survey of 15 and 17 May 1950  
Dwg. No. 6-21

Corps of Engineers, U. S. Army, 1950  
High water shore line changes  
Dwg. No. 6-21-1, Plate 7-1, App IV

Corps of Engineers, U. S. Army, 1950  
High water shore line changes  
Dwg. No. 6-21-2, Plate 7-2, App IV

Corps of Engineers, U. S. Army, 1950  
Monterey Bay, Offshore depth changes  
Dwg. No. 6-21-3, Plate 8-1, App IV

Corps of Engineers, U. S. Army, 1950  
Comparison of depth curves from condition surveys of  
Oct 1931, July 1938 and Dec 1945  
Dwg. No. 6-21-4, Plate 8-2, App IV

Corps of Engineers, U. S. Army, 1951\*  
Monterey Harbor condition survey of 29 Sept and 1 Oct 1951  
Dwg. No. 6-22 and 6-2-23

Corps of Engineers, U. S. Army, 1952  
Survey report on Monterey Harbor,  
Plan of Improvement of Monterey Harbor  
Dwg. No. 6-1-37

Corps of Engineers, U. S. Army, 1952\*  
Monterey Harbor condition survey of 20, 21, and 22 May 1952  
Dwg. No. 6-23 and 6-2-24

Corps of Engineers, U. S. Army, 1953  
Monterey Harbor dredging  
Dwg. No. 6-1-38

Corps of Engineers, U. S. Army, 1953  
Monterey Harbor, Before dredging survey of 14 May 1953  
Dwg. No. 6-24

Corps of Engineers, U. S. Army, 1953  
Monterey Harbor, After dredging survey of 7, 9 Aug 1953  
Dwg. No. 6-25 and 6-2-25

Corps of Engineers, U. S. Army, 1954\*  
Monterey Harbor, Condition survey of 3 and 4 Aug 1954  
Dwg. No. 6-26 and 6-2-26

Corps of Engineers, U. S. Army, 1955  
Monterey Harbor, Reconnaissance Survey of 28, 29 Sept 1955  
Dwg. No. 6-27

Corps of Engineers, U. S. Army, 1956  
Monterey Harbor, Condition survey of 26, 27 Nov 1956  
Dwg. No. 6-28

Corps of Engineers, U. S. Army, 1957  
Monterey Harbor dredging  
Dwg. No. 6-1-39

Corps of Engineers, U. S. Army, 1957  
Monterey Harbor before dredging survey of 2 Apr 1957  
Dwg. No. 6-29

Corps of Engineers, U. S. Army, 1957  
Monterey Harbor after dredging survey of 5 and 6 June 1957  
Dwg. No. 6-2-27

Corps of Engineers, U. S. Army, 1958  
Monterey Harbor, Plan of Improvement  
Dwg. No. 6-1-40

Corps of Engineers, U. S. Army, 1958  
Monterey Harbor, High water shore line changes  
Dwg. No. 6-21-5, Plate 7-1, App V

Corps of Engineers, U. S. Army, 1958  
Monterey Harbor, High water shore line changes  
Dwg. No. 6-21-5, Plate 7-2, App V

Corps of Engineers, U. S. Army, 1958  
Monterey Harbor, Off shore depth changes  
Dwg. No. 6-21-5, Plate 8-1, App V

Corps of Engineers, U. S. Army, 1958  
Monterey Harbor, Comparison of depth curves from condition  
surveys of Oct 1931 and July 1938 and Dec 1945  
Dwg. No. 6-21-5, Plate 8-2, App V

Corps of Engineers, U. S. Army, 1958  
Monterey Harbor, Reconnaissance Survey of 8 and 9 May 1958  
Dwg. No. 6-30

Corps of Engineers, U. S. Army, 1959  
Monterey Harbor, Condition survey of 30 June 1959  
Dwg. No. 6-2-28

Corps of Engineers, U. S. Army, 1959  
Monterey Harbor, Condition survey of 5 Nov 1959  
Dwg. No. 6-2-29

Corps of Engineers, U. S. Army, 1963  
Monterey Harbor Model study, Survey of 16-18, 24, 25, 29-31 July,  
1 and 2 Aug 1963  
Dwg. No. 6-31

Corps of Engineers, U. S. Army, 1963\*  
Monterey Harbor Topographic & Hydrographic Surveys  
from July to Aug 1963  
Dwg. No. 6-2-30, 7 sheets

Corps of Engineers, U. S. Army, 1936  
Monterey Harbor Topographic & Hydrographic Surveys  
from July to Aug 1963 and 15 September 1966  
Dwg. No. 6-2-31

Corps of Engineers, U. S. Army, 1966  
Monterey Harbor  
Dwg. No. 6-5-3, Plates A1, A2



U. S. Coast and Geodetic Survey 1851  
Preliminary Survey of the Bay of Monterey  
Hydrographic Survey No. H-296

U. S. Coast and Geodetic Survey, 1856  
Hydrography of Monterey Bay  
Hydrographic Survey No. H-558

U. S. Coast and Geodetic Survey, 1933  
Monterey Harbor  
Hydrographic Survey No. H-5415

U. S. Coast and Geodetic Survey, 1953-54  
Monterey Harbor  
Hydrographic Survey No. H-8068

LT Richard J. Lennox, U. S. Navy, 1969\*  
Monterey Harbor  
Hydrographic Survey of January 1969

## APPENDIX E

### COMPUTER PROGRAMS

The following computer programs were devised to reduce the hydrographic data. These programs are written in FORTRAN IV computer language.

```

*****
PROGRAM DIFFERENCE
*****

C THIS PROGRAM DETERMINES THE DIFFERENCE BETWEEN ANY TWO SURVEYS
C AND THEN UTILIZES SUBROUTINE METMAP TO GIVE A PICTORAL PRE-
C SENTATION OF THE CHANGE. CONTOURING INTERVAL IS CONTROLLED IN
C SUBROUTINE METMAPS CALLING ARGUMENT. THIS PROGRAM HAS PRINTED
C DATA CARDS OF THE DEPTH CHANGE AS PART OF THE OUTPUT.

DIMENSION DEPTH1(60,40),DEPTH2(60,40),DEPTH3(60,40),TITLE(24)
DO 101 I=1,60
DO 102 J=1,40
DEPTH1(I,J)=0.0
DEPTH2(I,J)=0.0
102 CONTINUE
101 CONTINUE
READ(5,200) TITLE
DO 103 I=1,60
READ(5,201)(DEPTH1(I,J),J=1,40)
103 CONTINUE
DO 104 I=1,60
READ(5,201)(DEPTH2(I,J),J=1,40)
104 CONTINUE

C AT THIS POINT SURTRACT DEPTH2 FROM DEPTH1 INORDER TO GET
C CONTOURE DEPTH CHANGE DEPTH3
C
DO 105 I=1,60
DO 106 J=1,40
DEPTH3(I,J)=DEPTH1(I,J)-DEPTH2(I,J)
106 CONTINUE
105 CONTINUE

C NOW USING SUBROUTINE METMAP CONTOUR DEPTH CHANGES
C
CALL METMAP(DEPTH3,60,40,TITLE,1.0,0.01,0.0,0.0,0,1)
WRITE(6,300)
WRITE(6,301)
DO 107 I=1,60
WRITE(6,302)I,(DEPTH3(I,J),J=1,20)
107 CONTINUE
WRITE(6,300)
WRITE(6,303)
DO 108 I=1,60
WRITE(6,302)I,(DEPTH3(I,J),J=21,40)
108 CONTINUE

C NOW PRODUCE REQUIRED OUTPUT DECK OF DEPTH3
C

```

```

DO 109 I=1,60
WRITE(7,304)(DEPTH3(I,J),J=1,40)
CONTINUE
109 FORMAT(20A4)
200 FORMAT(10F5.1)
201 FORMAT(1H1,T25,X,T6,3X,T1,5X,T2,5X,T3,5X,T4,5X,T5,5X,T6,5X,T7,5X,
301 *4X,T8,5X,T9,5X,T10,4X,T11,4X,T12,4X,T13,4X,T14,4X,T15,
*4X,T16,4X,T17,4X,T18,4X,T19,4X,T20)
302 FORMAT(//2X,T2,T6,20F6.1)
303 FORMAT(//,T6,3X,T1,4X,T2,4X,T3,4X,T4,4X,T5,4X,T6,4X,T7,4X,T8,4X,T9,4X,T10,4X,T11,4X,T12,4X,T13,4X,T14,4X,T15,4X,T16,4X,T17,4X,T18,4X,T19,4X,T20)
*4X,T26,4X,T27,4X,T28,4X,T29,4X,T30,4X,T31,4X,T32,4X,T33,4X,T34,4X,T35,4X,T36,4X,T37,4X,T38,4X,T39,4X,T40)
304 FORMAT(10F5.1)
RETURN
END

```

```

*****
PROGRAM      METMAP      *****
C
C THIS SUBROUTINE OBTAINED FROM THE NAVAL POSTGRADUATE SCHOOL
C COMPUTER LIBRARY PRODUCES CONTOURS OF POINTS WITHIN A SPECIFIED
C GRID SYSTEM. CALLING ARGUMENTS ARE AS FOLLOWS:
C   Y = TWO DIMENSIONAL FIELD TO BE CONTOURED
C   N = NUMBER OF ROWS I IN THE ARRAY
C   T = TITLE FOR PRINTOUT, 96 ALPHANUMERIC CHARACTERS
C   BND = BANDWIDTH DESIRED FOR CONTOUR
C   AZ = SCALING CONSTANT, THE FIRST THREE NUMBERS
C        TO THE RIGHT OF THE DECIMAL POINT ARE
C        PRINTED OUT.
C   BZ = ADDITIVE CONSTANT - USUALLY 0.0
C   AMIN = MINIMUM VALUE TO BE CONTOURED
C   IJT = 0 MEANS SUBROUTINE WILL COMPUTE MIN VALUE
C   ICCN = 1 IF CONTOURING DESIRED
C   ICCN = 0 IF NO CONTOURS DESIRED
C
C NOTE: GRID ORIGIN I=1, J=1 IS IN UPPER LEFT HAND CORNER OF
C GRID: I INCREASES DOWNWARD, J INCREASES TO RIGHT.
C
SUBROUTINE METMAP(Y,N,M,T,BND,AZ,BZ,AMIN,IJT,ICON)
REAL*4 IH,KG,ITJT
DIMENSION A(140),B(140),C(140),D(140),IH(20),Y(N,M),TP(5),XMT(5),
IBT(5),KG(10),T(24)

DATA DUE/4H /,EPL/4H+ /,EMI/4H- /,IH/1H0,IH /,IH1,IH /,IH2,
1IH /,IH3,IH /,IH4,IH /,IH5,IH /,IH6,IH /,IH7,IH /,IH8,IH /,
2IH0,IH1,IH2,IH3,IH4,IH5,IH6,IH7,IH8,IH9/,BLK/4H /
YMIN=Y(1,1)
YMAX=Y(1,1)
DO 20 I=1,M
DO 10 J=1,N
YMIN=AMINI(YMIN,Y(J,I))
YMAX=AMAXI(YMAX,Y(J,I))
CONTINUE
CONTINUE
DELY=YMAX-YMIN
IF(BND) 25,25,30
AND=DELY/15.0
25 IF (AMIN-YMIN) 31,31,32
30 IF (IJT) 33,32,33
31 IF (IJT) 33,32,33

```

```

MNMAP001
MNMAP004
MNMAP005
MNMAP006
MNMAP007
MNMAP008
MNMAP009
MNMAP011
MNMAP012
MNMAP013
MNMAP014
MNMAP015
MNMAP016
MNMAP017
MNMAP018
MNMAP019
MNMAP020
MNMAP021
MNMAP022

```



MNMAP023  
MNMAP024  
MNMAP025  
MNMAP026  
MNMAP027  
MNMAP028  
MNMAP029  
MNMAP030  
MNMAP031  
MNMAP032  
MNMAP033  
MNMAP034  
MNMAP035  
MNMAP036  
MNMAP037  
MNMAP038  
MNMAP039  
MNMAP040

```

32 PD=YMIN/RND
   PE=ARS(PD-INT(PD))
   IF (YMIN) 2,1,1
1  AMIN=YMIN-PE*8ND
   GO TO 33
2  AMIN=YMIN-(1.0-PE)*8ND
33 AHLD=A7
   IF(A7) 55,35,55
35 SM=AMAX1(ABS(YMIN),ARS(YMAX))
   NS=0
40 NS=NS+1
   SM=10.0*SM
   IF(SM-1.0)40,50,45
45 NS=NS-1
   SM=SM/10.0
   IF(SM-1.0)50,50,45
50 AHLD=10.0**NS
55 HBND=RND/2.0
   PRINT 70
   PRINT 6,T
6  FORMAT(5X,24A4,/)
   PRINT 57,AHLD,BZ
57 FORMAT(1H0,65H)

```

THE FOLLOWING TRANSFORMATION WAS PERFORMED ON THE  
INNMAMP043  
THREEMNMAP044  
MAP ) MNMAP045  
MNMAP047  
MNMAP050

```

54 FORMAT(/4X,5HYMAX=,E15.7,5X,5HYMIN=,F15.7)
   IF (ICON)5,58,5
5  PRINT 11,RND
11 FORMAT(2X,17H)

```

THE BAND WIDTH IS,E12.5,6H UNITS /4X,14HCONTOUR LEVE  
11LS

MNMAP052  
MNMAP053

```

53 YR=YTOP
   YTCP=YTOP+8ND
   I=1+1
   J=MOD(I,20)
   ITJ7=IH(J)
   IF(YR-YMAX)59,58,58
59 PRINT 61,YR,YTOP,ITJ7
61 FORMAT(/4X,E10.3,4H TO ,F10.3,2H =,1X,A1)
   GO TO 53
58 NCCP=0
   NCP=0
60 PRINT 70
70 FORMAT(1H1)

```

MNMAP055  
MNMAP056  
MNMAP057  
MNMAP058  
MNMAP059

MNMAP061  
MNMAP062  
MNMAP063

MNMAP064  
MNMAP065

```

PRINT 6,T
NLINF=0
NCCP=NCP+1
NCP=NCP+25
73 IF(NCP-M)80,80,75
75 NCP=M
80 J=C
NLINF=NLINF+1
LLINE=N-NLINF+1
C SET UP HEADING
85 IF(NCCP-1) 85,85,90
90 J=4
DO 100 I=1,135
A(I)=BLK
B(I)=RLK
C(I)=BLK
D(I)=RLK
100 CONTINUE
110 DO 160 L=NCCP,NCP
J=J+3
KI=L
IF(KI-100) 130,120,120
120 LL=KI/100
A(J)=KG(LL+1)
KI=KI-100*LL
GO TO 135
130 A(J)=KG(1)
135 J=J+1
IF(KI-10) 150,140,140
140 LL=KI/10
A(J)=KG(LL+1)
KI=KI-10*LL
GO TO 155
150 A(J)=KG(1)
155 J=J+1
A(J)=KG(KI+1)
160 CONTINUE
C SETUP FIRST ROW OF ARRAY
GO TO 260
170 NLINF=NLINF+1
LLINE=N-NLINF+1
IF(NLINE-N) 180,180,380
180 DO 190 I=1,135
A(I)=RLK
B(I)=RLK
C(I)=RLK
D(I)=RLK
190 CONTINUE

```

```

MNMAP067
MNMAP068
MNMAP070
MNMAP071
MNMAP072
MNMAP073
MNMAP074
MNMAP075
MNMAP076
MNMAP077
MNMAP079
MNMAP080
MNMAP081
MNMAP082
MNMAP083
MNMAP084
MNMAP085
MNMAP086
MNMAP087
MNMAP088
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MNMAP096
MNMAP097
MNMAP098
MNMAP099
MNMAP100
MNMAP101
MNMAP102
MNMAP103
MNMAP104
MNMAP105
MNMAP106
MNMAP107
MNMAP109
MNMAP110
MNMAP111
MNMAP112
MNMAP113

```

```

195 IF (ICON)105,260,105
    NCY=NCCP-1
    J=1
200 IF(NCY)200,200,210
    J=5
210 NCY=NCY+1
    IF(NCY-NCP) 220,220,260
220 IF(NCY-M) 230,260,260
230 NLINE=NLINE-1
    YD1=Y(NLINE,NCY)-Y(NLINE+1,NCY)
    YD2=Y(NLINE,NCY+1)-Y(NLINE+1,NCY+1)
    TP(1)=Y(NLINE,NCY)-0.25*YD1
    XMT(1)=Y(NLINE,NCY)-0.5*YD1
    BT(1)=Y(NLINE,NCY)-0.75*YD1
    TP(5)=Y(NLINE,NCY+1)-0.25*YD2
    XMT(5)=Y(NLINE,NCY+1)-0.5*YD2
    BT(5)=Y(NLINE,NCY+1)-0.75*YD2
    NLINE=NLINE+1
    D1=0.25*(TP(5)-TP(1))
    D2=0.25*(XMT(5)-XMT(1))
    D3=0.25*(BT(5)-BT(1))
    DO 240 I=2,4
    TP(I)=TP(I-1)+D1
    XMT(I)=XMT(I-1)+D2
    BT(I)=BT(I-1)+D3
240 CONTINUE
    DO 250 I=1,5
    J=J+1
    I1=MOD(IFIX((TP(I)-AMIN)/RND),20)+1
    I2=MOD(IFIX((XMT(I)-AMIN)/RND),20)+1
    I3=MOD(IFIX((BT(I)-AMIN)/RND),20)+1
    A(J)=IH(I1)
    B(J)=IH(I2)
    C(J)=IH(I3)
    CONTINUE
    GO TO 210
250 NCY=NCCP-1
    J=0
260 IF(NCY) 265,265,270
    J=-1
265 GO TO 330
270 NCY=NCY+1
    IF(NCY-NCP) 280,280,310
280 J=J+2
    THLD=AHLD*Y(NLINE,NCY)+B7
    IF(THLD) 285,290,200
285 D(J)=EMI
    GO TO 205

```

MNMAPI115  
MNMAPI116  
MNMAPI117  
MNMAPI118  
MNMAPI119  
MNMAPI120

MNMAPI120  
MNMAPI130  
MNMAPI131  
MNMAPI132  
MNMAPI133  
MNMAPI134  
MNMAPI135  
MNMAPI136  
MNMAPI137  
MNMAPI138  
MNMAPI139  
MNMAPI140  
MNMAPI141  
MNMAPI142  
MNMAPI143  
MNMAPI144  
MNMAPI145  
MNMAPI146  
MNMAPI147  
MNMAPI148  
MNMAPI149  
MNMAPI150  
MNMAPI151  
MNMAPI152  
MNMAPI153  
MNMAPI154  
MNMAPI156  
MNMAPI157  
MNMAPI158

```

250 D(J)=EPL
255 NUM=INT((ABS(THLD-INT(THLD)))*1000.0+0.5)
    NDS=100
    DO 300 KK=1,3
      J=J+1
      KI=NUM/NDS
      D(J)=KG(KI+1)
      NUM=NUM-KI*NDS
      NDS=NDS/10
    CONTINUE
    GO TO 270
310 IF(NCP-M) 360,320,320
320 IF(J-127)330,330,360
330 J=J+3
    KI=NLINE
    IF(KI-100) 340,335,335
    LL=KI/100
    D(J)=KG(LL+1)
    KI=KI-100*LL
    GO TO 343
340 D(J)=KG(1)
343 J=J+1
    IF(KI-10) 350,345,345
    LL=KI/10
    D(J)=KG(LL+1)
    KI=KI-10*LL
    GO TO 355
350 D(J)=KG(1)
355 J=J+1
    D(J)=KG(KI+1)
    IF(NCY-1) 270,270,360
360 IF(NLINE-1)362,362,368
362 PRINT 370,(A(I),I=1,132),(B(IP1),IP1=1,132),(D(IP2),IP2=1,132)
368 GO TO 170
368 PRINT 370,(A(I),I=1,132),(B(IP1),IP1=1,132),(C(IP2),IP2=1,132),
1(N(IP3),IP3=1,132)
370 FORMAT(132A1)
    GO TO 170
380 DO 390 I=1,135
    A(I)=BLK
    R(I)=RLK
    C(I)=RLK
    D(I)=RLK
390 CONTINUE
    J=C
    IF(NCCP-1) 395,395,400
395 J=4
400 DO 430 L=NCCP,NCP

```

MNMAP159  
 MNMAP160  
 MNMAP161  
 MNMAP162  
 MNMAP163  
 MNMAP164  
 MNMAP165  
 MNMAP166  
 MNMAP167  
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 MNMAP189

MNMAP193  
 MNMAP195  
 MNMAP196  
 MNMAP197  
 MNMAP198  
 MNMAP199  
 MNMAP200  
 MNMAP201  
 MNMAP202  
 MNMAP203

```

J=J+3
KI=L
IF(KI-100) 410,405,405
405 LL=KI/100
C(J)=KG(LL+1)
KI=KI-100*LL
GO TO 412
C(J)=KG(1)
410 J=J+1
412 IF(KI-10) 420,415,415
415 LL=KI/10
C(J)=KG(LL+1)
KI=KI-10*LL
GO TO 422
C(J)=KG(1)
420 J=J+1
422 IF(KI-1) 430,425,425
C(J)=KG(KI+1)
430 CONTINUE
PRINT 370, (R(IP1), IP1=1,132), (C(IP2), IP2=1,132)
IF(NCP-M)60,500,500
500 RETURN
END

```

```

MNMAPP204
MNMAPP205
MNMAPP206
MNMAPP207
MNMAPP208
MNMAPP209
MNMAPP210
MNMAPP211
MNMAPP212
MNMAPP213
MNMAPP214
MNMAPP215
MNMAPP216
MNMAPP217
MNMAPP218
MNMAPP219
MNMAPP220
MNMAPP221
MNMAPP223
MNMAPP224
MNMAPP225

```





```

*****
SUBROUTINE      SCAN      *****
C
C SUBROUTINE SCAN WAS OBTAINED THROUGH THE COMBINED EFFORTS OF
C THE NAVAL POST GRADUATE SCHOOL COMPUTER FACILITY AND PROF. JENNINGS
C OF THE MATHEMATICS DEPARTMENT. THIS PROGRAM UTILIZES
C ADDITIONAL SUBPROGRAMS TO PRODUCE A CONTOURED GRAPH ON A CALCOMP
C PLOTTER. THE VARIOUS SUBPROGRAMS ARE TRACE, CALC, PLOTT AND DRAW.
C THE ONLY SUBPROGRAM WHICH REQUIRES ADDITIONAL INFORMATION IS
C PLOTT. M = MATRIX OF PCINTS FOR MATRIX A(I,J)
C M = VALUE OF I(MAX) FOR MATRIX A(I,J)
C NX = VALUE OF J(MAX) FOR MATRIX A(I,J)
C NY = PORTION OF I(MAX) DESIRED ON GRAPH
C CL = CONTOUR LEVELS

```

```

SUBROUTINE SCAN (AM, M, N, MX, NY, CL)
DIMENSION AM(MX,NY), REC(900), X(1800), Y(1800)
DIMENSION IPT(3,3), INX(8), INY(8)
COMMON /DAYHCF/ MT,NT,N1,IX,IY,IDX,IDY,ISS,IT,IV,NP,NQ,JT,
1 COMMON /INTFAC/ PY,REC,CV, IPT,INX,INY,DL,RA,THE
D=C.
R=1.
TH= 1.570796
NP=0
DL=D
RA=R
THE=TH
MT=M
NT=N
CV=CL
IF(I7W-120631) 1,3,1
1 IPT(1,1)=8
IPT(1,2)=1
IPT(1,3)=2
IPT(2,1)=7
IPT(2,3)=3
IPY(3,1)=6
IPT(3,2)=5
IPT(3,3)=4
INX(1)=-1
INX(2)=-1
INX(3)=0

```

```

INX(4)=1
INX(5)=1
INX(6)=1
INX(7)=0
INX(8)=-1
INY(1)=0
INY(2)=1
INY(3)=+1
INY(4)=+1
INY(5)=0
INY(6)=-1
INY(7)=-1
INY(8)=-1
IZW=120631
3 XT=MT
DO 58 J=1,900
58 REC(J)=0
ISS=0
2 MT1=MT-1
DO 110 I=1,MT1
IF (AM(I,1)-CV) 55,110,110
55 IF (AM(I+1,1)-CV)110,57,57
57 IX=I+1
IY=1
IDY=-1
IDY=0
CALL TRACE (AM,MX, NY)
110 CONTINUE
NT1=NT-1
DO 20 I=1,NT1
IF (AM(MT,I)-CV) 15,20,20
15 IF (AM(MT,I+1)-CV) 20,17,17
17 IX=MT
IY=I+1
IDY=0
IDY=-1
CALL TRACE (AM,MX, NY)
20 CONTINUE
22 DO 30 I=1,MT1
MT2=MT+1-I
IF (AM(MT2,NT)-CV) 25,30,30
25 IF (AM(MT2-1,NT)-CV) 30,27,27
27 IX=MT2-1
IY=NT
IDY=1
IDY=0
CALL TRACE (AM,MX, NY)
30 CONTINUE

```

```

DO 40 I=1,NT1
NT2=NT+1-I
IF (AM(1,NT2)-CV) 35,40,40
35 IF (AM(1,NT2-1)-CV) 40,37,37
37 IX=1
IY=NT2-1
IDX=0
IDY=1
CALL TRACE (AM,MX, NY)
40 CONTINUE
ISS=1
NT1=NT-1
MT1=MT-1
DO 10 J=2,NT1
DO 10 I=1,MT1
IF (AM(I,J)-CV) 5,10,10
5 IF (AM(I+1,J)-CV) 10,7,7
7 COM=100*(I+1)+J
IF (NP) 12,11,12
12 DO 9 ID=1,NP
IF (REC(ID)-COM) 9,10,9
9 CONTINUE
11 IX= I+1
IY=J
IDX=-1
IDY=0
CALL TRACE (AM,MX, NY)
10 CONTINUE
RETURN
END

```

```

***** SUBROUTINE TRACE *****
C THIS SUBROUTINE IS PART OF SCAN AND REQUIRES NO ALTERATIONS.

```

```

SUBROUTINE TRACE (AM,MY,NY)
DIMENSION AM(MY,NY),REC(900), X(1800), Y(1800)
DIMENSION IPT(3,3), INX(8),INY(8)
COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,N ,JT,
1 PY,REC,CV, IPT,INX,INY,DL,RA,THE
COMMON /INTFAC/ X,Y
PY=0.0
RC= COS (THE)*RA
RS= SIN (THE)*RA
501 JT=0
N=0
IXC=IX
IYC=IY
ISX=IDX+2
ISY=IDY+2
IS=IPT(ISX,ISY)
JTB=0
ISC=IS
JTF(IS-8)18,18,17
ISC=IS-8
IT=0
17 18 CONTINUE
18 5 CALL CALC (AM,MY,NY)
N7=N
N=NZ
IF (IT+JT-1) 49,49,47
XS=X(N-1)
YS=Y(N-1)
X(N-1)=X(N)
Y(N-1)=Y(N)
X(N)=XS
Y(N)=YS
49 IS=IS+1
JT=IT
9 IF (IS-9) 8,7,7
7 8 IS=IS-8
IDX=INX(IS)
IDY=INY(IS)
IX2=IX+IDX
IY2=IY+IDY

```



```

308 JTB=JTB+1
309 IF (JTB-1799) 51,51,308
103 PRINT
103 FORMAT(1H0,23HA CONTOUR LINE AT LEVEL,E12.5,21H WAS TERMINATED AT
1X=E12.5,3H Y=E12.5/
2 48H BECAUSE IT CONTAINED MORE THAN 1799 PLOT POINTS )
2 RETURN

C SHOULD TEST HERE FOR MAXIMUM NUMBER OF PLOTTABLE POINTS IN SEGMENT.
51 CONTINUE
10 IF (ISS) 10,10,20
20 IF (IX-IX0) 12,21,12
21 IF (IY-IY0) 12,22,12
22 IF (IS-IS0) 12,23,12
23 CONTINUE
CALL CALC (AM,MY,NY)
GO TO 73
10 IF (IX2) 13,50,13
13 IF (IX2-MT) 19,19,50
19 IF (IY2) 11,50,11
11 IF (IY2-NT) 12,12,50
12 IF (CV-AM(IY2,IY2)) 206,206,5
206 IF (IDX**2+IDY**2-1) 213,6,213
213 DCP=(AM(IX,IY)+AM(IX2,IY)+AM(IX,IY2)+AM(IX2,IY2))/4.0
217 IF (DCP-CV) 5,217,217
214 IF (INX(IS-1)) 214,215,214
1X=IX+IDX
IDX=-IDX
DY=2.0
CALL CALC (AM,MY,NY)
IX=IX+IDX
GO TO 6
215 IY=IY+IDY
IDY=-IDY
PY=2.0
CALL CALC (AM,MY,NY)
IY=IY+IDY
IF (AM(IX-1,IY) - CV) 306,16,16
306 NP=NP+1
RFC(NP)=100*IX+IY
16 IS=IS+5
IX=IX2
IY=IY2
GO TO 9
50 XT=MT
307 IF (AM(IX-1,IY)-CV) 307,73,73
NP=NP+1
RFC(NP)=100*IX+IY

```

```
73 DO 74 I=1,N
    X(I)=X(I)+RC*Y(I)
74 Y(I)=RS*Y(I)
    CALL PLOTT (N)
    RETURN
END
```

```

*****
SUBROUTINE      CALC      *****
C      THIS SUBROUTINE IS PART OF SCAN AND REQUIRES NO ALTERATIONS.

```

```

SUBROUTINE CALC      (AM,MY,NY)
DIMENSION AM(MY,NY),REC(900),X(1800),Y(1800)
DIMENSION IPT(3,3),INX(8),INY(P)
COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,N ,JT,
PY,REC,CV, IPT,INX,INY,DL,RA,THE
1 COMMON /INTFAC/ X,Y
IT=0
N=N+1
IF (IDX**2 + IDY**2 -1) 20,1,20
1 IF (IDX) 10,2,10
2 X(N)=IX
Z=IY
IY2=IY+IDY
DY=IDY
41 Y(N) = ((AM(IX,IY)-CV)/(AM(IX,IY)-AM(IX,IY2))) *DY + 7
1C Y(N)=IY
W=IX
DX=IDX
IX2=IX+IDX
44 X(N) = ((AM(IX,IY)-CV)/(AM(IX,IY)-AM(IX2,IY))) *DX +W
2C RETURN
IX2=IX+IDX
IY2=IY+IDY
W=IX
Z=IY
DX=IDX
DY=IDY
NCP=(AM(IX,IY)+AM(IX2,IY)+AM(IX,IY2)+AM(IX2,IY2))/4.0
24 IF (PY-2.0) 24,21,24
21 IF (DCP-CV) 21,21,25
23 AL=AM(IX,IY)-DCP
27 V=.5*(AL+DCP -CV)/AL
X(N)=V*DX+W
Y(N)=V*DY+Z
PY=0.0
RETURN
25 IT=1
33 AL=AM(IX2,IY2)-DCP
V=.5*(AL+NCP-CV)/AL

```

```
28 X(N)=-V*DX+W + DX  
   Y(N)=-V*DY+Z + DY  
   RETURN  
   END
```

```

*****          SUBROUTINE      PLOTT          *****
C
C   THIS SUBROUTINE IS USED TO DETERMINE THE SCALING REQUIREMENTS
C   FOR A PARTICULAR GRAPH AND TO CALL SUBROUTINE DRAW FROM THE
C   COMPUTER FACILITY LIBRARY.

      SUBROUTINE PLOTT(NP)
      COMMON /INTFAC/ X(1800), Y(1800)
      COMMON /LENNCX/ ITITLE, LABEL, IJEN, CLEVEL
      REAL*8 ITITLE(12)
      REAL*4 LABEL
      DIMENSION XP(1800), YP(1800)
      IF (NP .LE. 900) GO TO 5
      NP = 900
5    DO 10 I=1,NP
C
C   CONVERT MATRIX NOTATION TO COMPUTER GRID NOTATION, -X IS USED AS
C   ORIGIN IS IN UPPER LEFT HAND CORNER OF GRID.
      XP(I)=Y(I)
      YP(I)=-X(I)
      WRITE (6, 504) NP, CLEVEL
      IF (NP - 10) 30, 30, 11
      10  WRITE (6, 502) (I, XP(I), YP(I), I=1,NP)
      IF (IJEN - 1) 15, 15, 20
      15  MODCUR = 1
      GO TO 25
      20  MODCUR = 2
      25  CALL DRAW(NP, XP, YP, MODCUR, 0, LABEL, ITITLE, 5.0, 5.0, 12, 0,
      *2, 2, 8, 12, 1, LAST)
      WRITE (6, 501) LAST
      IJEN = IJEN + 1
      IF (IJEN - 1) 110, 110, 1
      110  FORMAT (4(1X, 13, 2F9.2, 3X))
      501  FORMAT (4(1X, 13, 2F9.2, 3X))
      502  FORMAT (///, 110, F10.2)
      504  RETURN
      30  END

```



```

*****
PROGRAM      VOLUME      *****
C
C THE PURPOSE OF THIS PROGRAM IS TO COMPUTE THE VOLUME CHANGE FROM
C SURVEY TO SURVEY FOR EACH 50 X 50 SQUARE IN THE GRID SYSTEM.
C THIS PROGRAM UTILIZES OUTPUT DECK FROM PROGRAM DIFFERENCE FOR
C THE INPUT DATA.
C
C FIRST COMPUTE AVERAGE HEIGHT FOR GRID SQUARES USING FOUR POINTS
C
C DIMENSION DEPTH3(60,40),AVGHT(60,40),VOL(60,40)
C DO 101 I=1,60
C READ(5,201)(DEPTH3(I,J),J=1,40)
C FORMAT(10F5.1)
201 CONTINUE
101 CONTINUE
C DO 102 I=1,60
C DO 103 J=1,40
C AVGHT(I,J)=0.0
103 CONTINUE
102 CONTINUE
C DO 104 I=1,59
C DO 105 J=1,39
C AVGHT(I,J)=(DEPTH3(I,J)+DEPTH3(I+1,J)+DEPTH3(I,J+1)+
C *J+1))/4.0
105 CONTINUE
104 CONTINUE
C
C NOW ZEROIZE ALL GRID SQUARES NOT UTILIZED IN AREA OF INTEREST.
C
C DO 106 J=15,17
C AVGHT(1,J)=0.0
106 CONTINUE
C DO 107 J=17,20
C AVGHT(2,J)=0.0
107 CONTINUE
C DO 108 J=20,22
C AVGHT(3,J)=0.0
108 CONTINUE
C DO 109 J=22,25
C AVGHT(4,J)=0.0
109 CONTINUE
C DO 110 J=25,27
C AVGHT(5,J)=0.0
110 CONTINUE
C DO 111 J=27,31
C AVGHT(6,J)=0.0
111 CONTINUE
C DO 112 J=1,3
C AVGHT(6,J)=0.0

```

```

112 CONTINUE
    DO 113 J=29,32
    AVGHT(7,J)=0.0
113 CONTINUE
    DO 114 I=7,11
    AVGHT(I,3)=0.0
114 CONTINUE
    DO 115 I=7,25
    AVGHT(I,32)=0.0
115 CONTINUE
    DO 116 J=32,37
    AVGHT(25,J)=0.0
116 CONTINUE
    DO 117 J=4,5
    AVGHT(11,J)=0.0
117 CONTINUE
    DO 118 I=12,24
    AVGHT(I,5)=0.0
118 CONTINUE
    DO 119 I=24,28
    AVGHT(I,4)=0.0
119 CONTINUE
    DO 120 I=26,59
    AVGHT(I,37)=0.0
120 CONTINUE
    DO 121 I=28,33
    AVGHT(I,5)=0.0
121 CONTINUE
    DO 122 I=33,35
    AVGHT(I,6)=0.0
122 CONTINUE
    DO 123 I=35,37
    AVGHT(I,7)=0.0
123 CONTINUE
    DO 124 I=37,38
    AVGHT(I,8)=0.0
124 CONTINUE
    DO 125 I=38,39
    AVGHT(I,9)=0.0
125 CONTINUE
    DO 126 I=39,48
    AVGHT(I,10)=0.0
126 CONTINUE
    DO 127 I=48,51
    AVGHT(I,11)=0.0
127 CONTINUE
    DO 128 I=51,53
    AVGHT(I,12)=0.0

```

```

128 CONTINUE
DO 129 I=53,54
  AVGHT(I,13)=0.0
129 CONTINUE
DO 130 J=14,18
  AVGHT(54,J)=0.0
130 CONTINUE
DO 131 J=18,21
  AVGHT(55,J)=0.0
131 CONTINUE
DO 132 J=21,24
  AVGHT(56,J)=0.0
132 CONTINUE
DO 133 J=24,29
  AVGHT(57,24)=0.0
  AVGHT(58,J)=0.0
133 CONTINUE
DO 134 J=29,36
  AVGHT(59,J)=0.0
134 CONTINUE

      INSERT VARIOUS SUBROUTINES AS REQUIRED TO ZEROIZE SUBSEQUENT
      GRID SQUARES IF AREAS BEING COMPARED ARE NOT OF SIMILAR SIZE.

      CALL AVGH11(AVGHT)
      CALL AVGH12(AVGHT)
      WRITE(6,299)
      WRITE(6,300)
DO 139 I=1,60
  WRITE(6,301)I,(AVGHT(I,J),J=1,20)
139 CONTINUE
  WRITE(6,302)
DO 140 I=1,60
  WRITE(6,301)I,(AVGHT(I,J),J=21,40)
140 CONTINUE
300 FORMAT(/,16,3X,11,5X,12,5X,13,5X,14,5X,15,5X,16,5X,17,
*5X,18,5X,19,5X,10,4X,11,4X,12,4X,13,4X,14,4X,15,
*4X,16,4X,17,4X,18,4X,19,4X,20)
301 FORMAT(/,2X,12,16,20F6.1)
302 FORMAT(1H1,16,3X,21,4X,22,4X,23,4X,24,4X,25,
*4X,26,4X,27,4X,28,4X,29,4X,30,4X,31,4X,32,
*4X,33,4X,34,4X,35,4X,36,4X,37,4X,38,4X,39,4X,40)
299 FORMAT(1H1,T50,'AVERAGE HEIGHTS FOR GRID SQUARES:')

```

C  
C  
C  
C

NOW USING COMPUTED VALUES OF AVERAGE HEIGHT COMPUTE THE  
 VOLUME CHANGE FOR EACH GRID SQUARE, GRID SQUARE IS 2500 SQFT.

C  
C  
C



```

148 TVCL=VOL(I,J)+TVCL
149 CONTINUE
150 CONTINUE
151 WRITE(6,309) TVCL
152 TVCL2=TVOL/9.0
153 WRITE(6,310) TVCL2
309 FORMAT(IH1,I10,'TOTAL VOLUME CHANGE.....',F10.1,' CUBIC FEET')
310 FORMAT(///,I10,'TOTAL VOLUME CHANGE.....',F10.1,' CUBIC YARDS')
      RETURN
      END

```



```

*****
PROGRAM STATISTIC *****
C THIS PROGRAM IS USED TO COMPUTE THE STATISTICAL PARAMETERS
C DESIRED IF ., STANDARD DEVIATION, LEAST SQUARE FIT LINE AND ETC.
C INPUT FOR THIS PROGRAM IS IN THE FORM OF X(N),Y(N) PLOTTED PAIRS.
C THIS PROGRAM USES SURROUTINE PLOTP TO PRODUCE THE GRAPHICAL
C OUTPUT.

      DIMENSION X(15),Y(15),R(15),A(2,2),B(2),C(2),V(15),E(80),F(80)
1  G(80),H(80),Q(15),T(2),S(2)
      READ(5,200)(X(I),I=1,15)
      DO 1 K=1,44
      N=15
      READ(5,201) (Y(I),I=1,15)
      DO 2 I=1,15
      Y(I)=-Y(I)
2  CONTINUE
      DO 3 J=1,15
      X1=0.0
      X1=X1+X(J)
3  Y1=0.0
      DO 4 J=1,15
      Y1=Y1+Y(J)
4  XX=0.0
      DO 5 J=1,15
      XX=XX+X(J)**2
5  XY=0.0
      DO 6 J=1,15
      XY=XY+X(J)*Y(J)
6  A(1,1)=N
      A(1,2)=X1
      A(2,1)=X1
      A(2,2)=XX
      B(1)=Y1
      B(2)=XY
      CALL SIMQ(A,B,2,KS)
      C(1)=B(1)
      C(2)=B(2)
      DO 8 I=1,15
8  V(I)=(C(2)*X(I)-Y(I)+C(1))/(SQRT(C(2)*C(2)+1.0))
      VV=0.0
      DO 11 L=1,15
11  VV=VV+V(L)**2
      V1=0.0
      DO 12 L=1,15
12  V1=V1+V(L)
      VAR=(VV-V1**2/N)/(N-1)
      SD=SQRT(VAR)

```

```

E(1)=32.62
E(1)=C(1)+C(2)*E(1)
DO 10 I=2,80
E(I)=E(I-1)+0.45575
E(I)=C(1)+C(2)*E(I)
10 CONTINUE
WRITE(6,300) K
CALL PLOTP(X,Y,15,1)
CALL PLOTP(E,F,80,2)
CALL STAT2(X,Y,G,H,CC,SD2,VAR2)
CALL PLOTP(G,H,60,3)
WRITE(6,301) SD,C(2),SD2,CC
1 CONTINUE
200 FORMAT(15F5.2)
201 FORMAT(15F5.1)
300 FORMAT(1H1,/,T15,'GRID POINT',I2,/)
301 FORMAT(/T26,'1932-1969',5X,'STD DEV',F6.2,5X,'TREND',F8.5,' FT
1PER YR',/,T26,'1947-1969',5X,'STD DEV',F6.2,5X,'TREND',F8.5,' FT
2PER YR',/)
RETURN
END

```

```

SUBROUTINE STAT2(X,Y,G,H,CC,SD2,VAR2)
DIMENSION X(15),Y(15),R(15),A(2,2),B(2),C(2),V(15),E(80),F(80)
1,G(80),H(80),Q(15)
N=8
DO 13 J=1,8
13 Q(J)=X(J+7)
DO 14 J=1,8
14 Y(J)=Y(J+7)
X1=0.0
DO 3 J=1,8
3 X1=X1+Q(J)
Y1=0.0
DO 4 J=1,8
4 Y1=Y1+Y(J)
XX=0.0
DO 5 J=1,8
5 XX=XX+Q(J)**2
XY=0.0
DO 6 J=1,8
6 XY=XY+Q(J)*Y(J)
A(1,1)=N
A(1,2)=X1
A(2,1)=X1

```

```

A(2,2)=XX
B(1)=YI
R(2)=XY
CALL SIMQ(A,B,2,KS)
C(1)=B(1)
C(2)=R(2)
DO 8 I=1,8
  8 V(I)=(C(2)*Q(I)-Y(I)+C(1))/(SORT(C(2)*C(2)+1.0))
  11 VV=0.0
  DO 11 L=1,8
    VV=VV+V(L)**2
  DO 12 L=1,8
    VI=V1+V(L)
  12 VAR=(VV-VI**2/N)/(N-1)
  SD=SORT(VAR)
  G(1)=47.08
  H(1)=C(1)+C(2)*G(1)
  DO 10 I=2,49
    G(I)=G(I-1)+0.45575
    H(I)=C(1)+C(2)*G(I)
  10 CONTINUE
  CC=C(2)
  SD2=SD
  VAR2=VAR
  RETURN
END

```

```

*****
SUBROUTINE PLOTP
*****
THIS SUBROUTINE IS USED IN CONJUNCTION WITH PROGRAM STATISTIC AND
PLOTS THE DATA POINTS AND THE VARIOUS LEAST SQUARE LINES CALLED
FOR. VALUES USED IN CALLING STATEMENT ARE:
X = NAME GIVEN TO X AXIS
Y = NAME GIVEN TO Y AXIS
NN = NUMBER OF POINTS TO BE PLOTTED IE.,
MODCUR = 1 SIGNIFYS WHICH CURVE IS BEING PLOTTED IE.,
= 2 THIS IS FIRST CURVE
= 3 THIS IS INTERMEDIATE CUPVE
= 4 THIS IS FINAL CURVE

```

```

C***
SUBROUTINE PLOTP(X,Y,NN,MODCUR)
GUAGE INPUT & FIND MAX & MIN FOR X & Y: CALL UTPLOT
DIMENSION X(51), Y(51), RANGE(4)
EQUIVALENCE (RANGE(1),XMAX), (RANGE(2),XMIN), (RANGE(3),YMAX),
(RANGE(4),YMIN)
1 IF(MODCUR.EQ.0.CR.MODCUR.EQ.1) GO TO 40
GO TO 400
40 XMAX=-1.E20
XMIN=1.E20
YMAX=-1.E20
YMIN=1.E20
DO 1 I=1,NN
IF(X(I)-XMAX) 6,6,2
XMAX=X(I)
YXMAX=Y(I)
IF(X(I)-XMIN) 3,3,7
XMIN=X(I)
YXMIN=Y(I)
IF(Y(I)-YMAX) 8,8,4
YMAX=Y(I)
XYMAX=X(I)
IF(Y(I)-YMIN) 5,5,1
YMIN=Y(I)
XYMIN=X(I)
CONTINUE
1 400 IF(MODCUR.EQ.2.CR.MODCUR.EQ.3) GO TO 50
CALL UTPLOT(X,Y,NN,RANGE,1,MODCUR)
GO TO 70
50 CALL UTHOLD(X,Y,NN,RANGE,1,MODCUR)
70 IF(MODCUR.NE.3) RETURN
WRITE(6,101) YMAX, XYMAX, YMIN, XYMIN

```

```

101  FORMAT('OMAX Y='1PE12.4,' AT X='E12.4,20X,'MIN Y=' E12.4,' AT X='
      E12.4)
      WRITE(6,100) XMAX, YXMAX, XMIN, YXMIN
100  FORMAT('OMAX X='1PE12.4,' AT Y='E12.4,20X,'MIN X=' E12.4,' AT Y='
      E12.4)
      RETURN
      END

```

```

SUBROUTINE UTPLOT (X, Y, NDATA, RANGE, KKZ, MODCUR)
DIMENSION GRID(61,91), XSCALE(5), YSCALE(7)
DIMENSION X (1), Y (1), RANGE(4)
INTEGER*2 GRID, BLANK, DCT, XCHAR(4)/1H., 1H., 1H., 1H./
DATA DOT, BLANK/Z4R40, Z4040/

```

```

GRID IS THE MATRIX USED TO PLOT THE POINTS

```

```

IERR=0
XMAX=RANGE(1)
XMIN=RANGE(2)
YMAX=RANGE(3)
YMIN=RANGE(4)

```

```

CHECKING X AND Y POINTS AND PLOTTING THESE OUT OF RANGE
AT THE MARGIN

```

```

DO 30 I=1, NDATA, KKZ
IF (X (I)-XMAX) 205, 205, 220
220 X (I)=XMAX
IERR=IERR+1
GOTO 210
205 IF (X (I)-XMIN) 203, 210, 210
203 X (I)=XMIN
IERR=IERR+1
210 IF (Y (I)-YMAX) 215, 215, 212
212 Y (I)=YMAX
IERR=IERR+1
GOTO 30
215 IF (Y (I)-YMIN) 217, 30, 30
217 Y (I)=YMIN
IERR=IERR+1

```

```

30 CONTINUE
PLOTTING X AND Y AXIS , IF NECESSARY

```



4500  
4510  
4520  
4530  
4540  
4550  
4560  
4570  
4580  
4590  
4600  
4610  
4620  
4630  
4640  
4650  
4660  
4670  
4680  
4690  
4700  
4710  
4720

4740  
4750

4770  
4780  
4790

4800  
4810  
4820  
4830  
4840  
4850

```

XCRANGE=XMAX-XMIN
YCRANGE=YMAX-YMIN
BLANKING OUT MATRIX--(GRID)
DO 300 I=1,61
DO 301 JJ=1,81
GRID(I,JJ)=BLANK
CONTINUE
YTEST=YMAX*YMIN
XTEST=XMAX*XMIN
IF(XTEST)1,222,222
222 IF(YTEST)333,444,444
1 IYAXIS=80.*(-XMIN)/XCRANGE+1.5
DO 40 I=1,61
GRID(I,IYAXIS)=DOT
GOTO 222
333 IXAXIS=60.*YMAX/YCRANGE+1.5
DO 60 I=1,81
60 GRID(IXAXIS,I)=DOT
PLACING POINTS IN THEIR PROPER GRID POSITIONS
ENTRY UTHOLD(X,Y,NDATA,RANGE,KKZ,MODCUR)
IF(MODCUR.EQ.0.OR.MODCUR.EQ.1)JSET=0
JSET=JSET+1
IF(JSET.GT.4) JSET=1
DO 700 I=1,NDATA,KKZ
IPTX=60.*(YMAX-Y(I))/YCRANGE+1.5
IPTY=80.*(X(I)-XMIN)/XCRANGE+1.5
IF(IPTX.GT.61.OR.IPTY.GT.81) GO TO 70
IF(IPTX.LE.0.OR.IPTY.LE.0)GO TO 70
GRID(IPTX,IPTY) = XCHAR(JSET)
GO TO 700
700 IERR=IERR+1
700 CONTINUE
COMPUTE PROPER SCALE NUMBERS
IF(MODCUR.EQ.0.OR.MODCUR.EQ.1) GO TO 9000
IF(MODCUR.EQ.2) RETURN
GO TO 922
9000 XINCR=XCRANGE/4.
YINCR=YCRANGE/4.
XSCALE(1)=XMAX
YSCALE(1)=YMAX
DO 80 I=2,5
80 XSCALE(I)=XSCALE(I-1)-XINCR

```

```

      DO 81 I=2,7
      81 YSCALE(I)=YSCALE(I-1)-YINCR
      C
      C      OUTPUT SECTION WITH GRAPH
      C
      IF(MODCUR.EQ.0.CR.MCDCUR.EQ.3)GO TO 922
      RETURN
      17 FORMAT(22X,
      1P,E10.3,4(10X,E10.3)/25X,2H**,8(10H+*****),3H+**)
      922 1 WRITE(6,17) XSCALE(5),XSCALE(4),XSCALE(3),XSCALE(2),XSCALE(1)
      II=1
      I=C
      DO 101 IK=1,61
      101 IF(I)91,91,92
      91 WRITE(6,18) YSCALE(II), (GRID(IK,IX), IX=1,81),YSCALE(II)
      18 1 FORMAT(13X,1P
      1E10.3,2X,1H+,1X,81A1,1X,1H+,2X,E10.3)
      II=II+1
      GO TO 102
      92 WRITE(6,19) (GRID(IK,IX), IX=1,81)
      19 FORMAT(25X,1H*,1X,81A1,1X,1H*)
      102 I=I+1
      103 IF(I-10)101,103,103
      103 I=0
      101 CONTINUE
      22 1 WRITE(6,22) XSCALE(5),XSCALE(4),XSCALE(3),XSCALE(2),XSCALE(1)
      22 1 FORMAT(25X,2H**,8(10H+*****),3H+**/ 1P
      22X,E10.3,4(10X,E10.3))
      1001 IF(IERR) 1000,1000,1001
      1001 WRITE(6,20) IERR
      1000 FORMAT(10X 'NUMBER OF POINTS OUT OF RANGE =', I4)
      1000 RETURN
      END

```

4860  
4870  
4880  
4890  
4900

4920  
4930  
4940  
4950  
4960  
4970  
4980

4990  
5000  
5010  
5020

5040  
5050  
5060  
5070  
5080

5100  
5110  
5120

## APPENDIX F

### MONTEREY HARBOR HYDROGRAPHIC SURVEY OF JANUARY 1969

The hydrographic survey conducted by Lieutenant R. J. Lennox, USN, is contained in the pocket attached to the back cover.

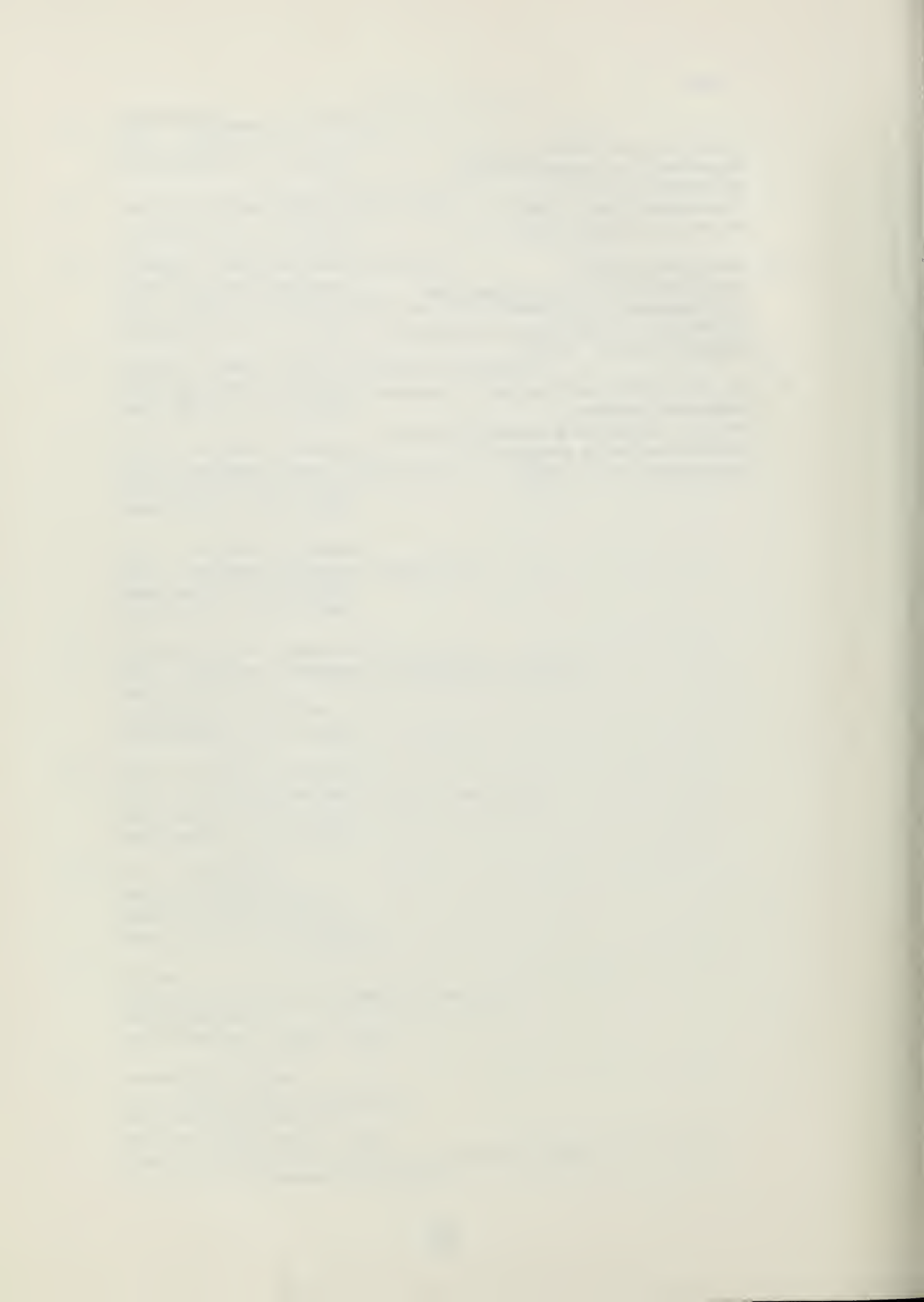
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13. ABSTRACT Bottom changes occurring in Monterey Harbor from 1932-1969 were analyzed by numerical computer methods using 15 selected hydrographic surveys. Results of the study indicate that the major portion of the harbor has been shoaling in the mean since 1932. The long-term shoaling rate has been 0.4 to 4.0 feet per decade in the beach and nearshore zones and along the breakwater; and less than 0.25 feet per decade in the stable outer harbor. The accretion rate averaged 17,500 cubic yards per year from 1932-1969, but only 7,100 cubic yards per year from 1947 to 1969. The shoaling is believed due to the construction of the Coast Guard Breakwater in 1931-1934. It is deduced that prior to 1960 the excess sand was carried into the harbor by littoral transport from Del Monte Beach and by wave currents around the breakwater. Construction of the solid wall on Wharf 2 in 1960 cut off the former sand supply. Local redistribution of sand in the beach and nearshore zones of the harbor is large and results in areas of significant accretion and erosion between surveys. Dredging operations have had only short-term effectiveness because the spoil has been retained within the harbor.			

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California Harbors						
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Hydrographic Surveys, Computer Analysis of						





